PB81-157877

Forecasts of the Quality and Composition of Solid Waste

International Research and Technology Corp.
McLean, VA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

May 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/5-80-001	2.	3. RECIPIENT'S ACCESSION NO. PB81 157877
4. TITLE AND SUBTITLE Forecasts of the Quantity and Composition of Solid Waste		5. REPORT DATE May 1980 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Ralph M. Doggett, Mary K. O'Farrell, and Andrea L. Watson		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS International Research and Technology Corporation 7655 Old Springhouse Road McLean, Virginia 22102		10. PROGRAM ELEMENT NO. 1DC818 11. CONTRACT/GRANT NO. 68-03-2649
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory--Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Oscar W. Albrecht 513/684-7881

16. ABSTRACT

The overall objective was to develop a methodology and predict the future quantities and composition of solid waste. A data base was compiled and a methodology developed to evaluate the effects of selected variables, including the extent of resource recovery, product lifetime, material and process substitutions, and economic growth. The methodology employs an interindustry forecasting model of the United States, which allows for specification of alternative values for critical variables.

Projections of the quantity and composition of solid waste involving 14 materials in 21 product categories are made to 1990 under five different scenarios. Results of the scenarios are compared with other studies, including the EPA Annual Reports to Congress on Resource Recovery and Waste Reduction, and projections by Midwest Research Institute in Base Line Forecasts of Resource Recovery, 1972-1990, prepared for EPA. Results of the scenarios suggest that the quantity of solid waste is likely to increase at a slower rate than the economy due to substitutions of heavy materials such as steel and glass by lighter materials such as aluminum, plastics and paper. The results also suggest that the future solid waste stream is strongly influenced by product lifetime, recycling rates, and technolgical changes.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Wastes Refuse disposal Scrap	Solid waste Forecasts Quantity Composition	68C
18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS (This Report) not classified	21. NO. OF PAGES 171
	20. SECURITY CLASS (This page) not classified	22. PRICE

PB81-157877

EPA-600/5-80-001
May 1980

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

Increasing quantities coupled with rising costs are of great concern to those charged with efficient management of solid waste. Policymakers need adequate data and reliable projections on which to develop strategies for achieving their objectives and goals. This report describes the various approaches available for estimating residential and commercial solid waste quantities and composition. It furnishes predictions to 1990, using an economic input-output model to reflect the impact of both economic growth and structural changes in the economy on the quantity and composition of the solid waste stream. The research project is one of the special studies mandated under Section 8002 of the Resource Conservation and Recovery Act of 1976 (PL94-580).

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

This research program was initiated with the overall objective of estimating the future quantity and composition of solid waste discards. A data base was compiled and a methodology was developed to evaluate the effects of a number of variables (including the extent of resource recovery initiatives, average product lifetimes, materials and process substitutions, and economic growth) on the quantity and composition of discards to the year 1990. The methodology employs an interindustry forecasting model of the United States economy, which allows for the specification of alternative values for critical variables.

Solid waste discards and recycling of fourteen materials in twenty-one product categories are estimated under five different sets of assumptions, or scenarios. Results of the scenarios are analyzed and compared with estimates from other studies, notably the EPA annual Reports to Congress on *Resource Recovery and Waste Reduction*, and projections by Midwest Research Institute in *Base Line Forecasts of Resource Recovery, 1972-1990* prepared for EPA. The results of the scenario suggest that the quantity of solid waste is likely to increase at a rate slower than that of the economy, due to substitutions away from heavy materials such as steel and glass, to lighter materials such as aluminum, plastics and paper. The results also suggest that the quantity and composition of future solid waste discards will be substantially determined by average product lifetimes, recycling rates, and technology change.

This report was submitted in fulfillment of Contract Number 68-03-2649 by International Research and Technology Corporation under the sponsorship of the U.S. Environmental Protection Agency. Computer support was provided by Control Data Corporation under Subcontract to IR&T. This report covers the period December 8, 1977 to December 23, 1978, and work was completed as of March 23, 1979.

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ACKNOWLEDGMENTS

The cooperation and assistance of Mr. Oscar Albrecht, the EPA project officer for this study, is gratefully acknowledged. Comments and suggestions by EPA consultant, Stedman Noble, proved valuable in the preparation of the final report. We would also like to thank Dr. Frank Smith of EPA's Office of Solid Waste Management Programs for his continued interest and assistance in this project. We are indebted to Mr. Raj Shah, Ms. Carol Metzger and Ms. Laura Beck of Control Data Corporation for programming support.

SECTION 1

OVERVIEW

The quantities and composition of solid waste disposed of in our landfills, incinerators, and dumps are largely determined by initiatives for waste reduction and resource recovery. The thrust of the Resource Conservation and Recovery Act of 1976, and of numerous state and local initiatives over the past several years has been to focus attention for the purpose of alleviating a growing national problem.* There are a number of promising programs in progress, including research and development in the area of mixed-waste processing technology, economic incentives for materials separation at the point of disposal, and the establishment of guidelines for returnable beverage containers. When evaluating the efficacy of these programs, it is important to recognize trends in the factors that determine the composition of solid waste. These include overall economic growth - an indication of the continuing increase in the demand for goods and services that ultimately generate waste - and within the economic growth context, the extent of materials substitution, technology change and recycling, and the average useful life of products produced. By quantifying these factors and by estimating their impacts on current and future waste loads, policy makers, solid waste managers, producers and consumers can more readily evaluate economic incentives, resource recovery programs, emerging technologies, and personal attitudes.

The purpose of this study was to compile a data base and develop a methodology to estimate the current and future quantity and composition of solid waste discards. Using the methodology, future solid waste loads can be estimated under alternative assumptions regarding recycling rates, product life, materials composition, technology change and general economic growth.

REVIEW OF PREVIOUS STUDIES**

This is by no means the first study to analyze the flow of materials through the economy for the purpose of estimating the characteristics of solid waste. Indeed, much of the data and design concepts for the methodology presented here have been derived from previous studies. Nonetheless, this study is unique in that it combines different approaches that have been used in previous studies.

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* See, for example, the annual reports to Congress on *Resource Recovery and Waste Reduction*, prepared by the U.S. Environmental Protection Agency.

** Much of this review of solid waste studies originally appeared in a previous IR&T report, *Forecasting the Composition and Weight of Household Solid Waste Using Input-Output Techniques*, Final Report, U.S. Environmental Protection Agency, November 1975, NTIS (PB 257499/AS), Vol. I, and NTIS (PB 257500/AS), Vol. II.

The previous studies vary greatly in their scope and objectives, but they can be generally classified by the approach used. The more common approach, called the output approach, is to analyze the materials contained in the waste stream after disposal. This approach is a sampling approach that requires the separation and weighing of materials at the disposal site. Sampling surveys for estimating the quantity of solid waste were first encouraged through legislative action. In enacting the Solid Waste Disposal Act of 1965, Congress provided for grants to state and interstate agencies of up to 50 percent of the costs of conducting surveys of solid waste disposal practices and problems. By 1968, 38 states, the District of Columbia, Puerto Rico, and three interstate agencies have received planning grants, and had started or completed solid waste surveys following a study design and reporting format established and coordinated by the U.S. Public Health Service. Data available on July 1, 1968, were published in their basic form (1), followed by a second publication in a more concise statistical format (2). Although widely distributed in this form, the final results of the completed survey were never formally evaluated or published. However, final figures have been analyzed and informally reported (3). Although the survey requested responses based on actual weights or measurements in cubic yards, most of the participating communities furnished only estimates of the waste loads they handled. Within the survey group, household and commercial solid wastes were found to be generated at an average rate of 4.15 pounds per capita per day. Adding demolition, construction, industrial, yard trash and other municipal solid wastes, this figure was raised to 5.32 pounds per day. Placing the survey data within a broader context, the informal final 1968 data analysis arrived at a somewhat lower figure of 4.01 pounds per capita per day for the residential, commercial, and institutional total. Subsequent critical analysis showed that the relatively few communities that made actual measurements to comply with the national survey requirements arrived at lower totals than those communities that reported estimates (4,5). It was then pointed out that the amount of paper waste estimated from samples for the 1968 survey would be greater than the estimates of paper entering the waste stream that are based on paper production data - even though the production-based data were in dry weights and the 1968 survey estimates would include varying amounts of water (6). Subsequent evaluation by F.A. Smith of EPA's Office of Solid Waste Management Programs recognized these shortcomings and suggested that, although the 1968 survey results may have overstated waste flows, the ensuing analytical efforts have not yielded information on which to base a more accurate estimate (7).

A less comprehensive survey conducted for the National Solid Waste Management Association in 1971 used volume data from major private waste collection organizations as a basis for estimating the weights of waste collected per capita (8). In general, the range of values estimated for commercial, demolition, industrial and other non-residential waste categories coincided with the range in EPA's final analysis of the 1968 survey results, but for residential waste it was approximately 30 percent higher.

The single, most significant drawback of the survey data, considered as a base from which to forecast future amounts of municipal wastes, is that regardless of the degree of accuracy of particular surveys, differences in samples, estimation techniques, and assumptions are likely to account for differences among the results to a greater degree than differences in actual household waste generation. For this reason, although the studies may relate to various years (i.e., 1967, 1970, and 1971), they cannot be treated as a time series. Standing alone, unlike a time series of production or consumption data, these surveys do not permit trend extrapolation in order to anticipate future waste levels. If the assumption is made that per capita solid waste output is a fixed value that is unaffected by such variables as changes in per capita income, packaging technology, or family size, then a value taken from these survey results could be multiplied by future population levels to arrive at an estimate of the weight of 1985 wastes. Because it has not been established whether these and other variables will not have a major effect on amounts of waste generated, these output or sampling surveys have not been used extensively to provide long-range estimates of amounts of wastes generated.

Both before and since the 1968 survey, there have also been a large number of analyses of the composition of household or municipal solid wastes. Representative examples include Oceanside, New York (9); Atlanta, Georgia (10); Cincinnati, Ohio (10); Flint, Michigan (10); Johnson City, Tennessee (10); San Diego, California (10); Berkeley, California (11); Raleight, North Carolina (12); Santa Clara County, California (13); New Orleans, Louisiana (14); and Madison, Wisconsin (15). Also, there have been several efforts to synthesize average or national composition figures from the many available samplings (16, 19). These studies customarily use composition categories such as food, yard wastes, glass, metal (sometimes disaggregated into ferrous and non-ferrous), paper, plastics, textiles, wood, leather and rubber. Variations among the recorded figures indicate that "average" composition may be a misnomer and that wide fluctuations in daily composition, varying by day of the week and month of the year, as well as by geographic location, are the norm.

The composition studies have been very helpful in previous estimation work aimed at identifying the resource potential implicit in national waste flows (7, 20). However, to an even greater degree than the surveys, each of the composition studies must be considered one point in its own discrete time series. Data from different places, collected over a short period of time and under conditions suggesting major seasonal and even weekly changes in composition, cannot be used as a base from which to extrapolate long-term change. In a study for the Energy Research and Development Administration, Resource Planning Associates made similar conclusions after a review of recent waste composition surveys (21).

The need for greater predictive capabilities, as well as other factors (such as the possibility that extrapolations from survey results may lead to unreliable results because of the difficulty of handling such variables as moisture content) have led to the use of industrial production statistics as a source of data from which to estimate the amounts and composition of household wastes. The approach has been called "input" estimation, to distinguish it from collection-based "output" oriented surveys.

The best known of the early input studies were the studies of packaging materials and non-packaging paper by Darnay and Franklin (22,23) of Midwest Research Institute (MRI). They have been followed by successor MRI studies on salvage markets, paper recycling and baseline forecasts of solid wastes by material and product category (24,26). Resource Planning Associates, Inc., has also started from industrial production data to arrive at waste generation estimates (4). Comprehensive reviews and evaluations of the earlier work were prepared by Frank A. Smith and Fred L. Smith, Jr., of EPA's Office of Solid Waste Programs, in 1974 and 1975 (7,27). Estimates of national totals and per capita daily average waste production and waste composition have been updated several times (7,27,28). In each study using the input approach, bulk production data on materials are corrected for imports and exports to yield an estimate of apparent domestic consumption. This estimate is corrected for process losses and for imports and exports of the relevant finished goods. The consumption estimates are then allocated by end-use to determine the quantities of materials by product category which potentially enter the relevant waste stream. This step, for example, determines what fraction of paperboard will end up as household waste. Allocated consumption data, thus obtained, are lagged to account for the durability of each category of end-use product. In each of these final use categories, the amount of material recovered is subtracted to yield an estimate of solid waste for that category. This development by Smith has resulted in the compilation of a six-year time series of solid waste estimates, the only one of its kind.

There are several difficulties implicit in this form of analysis. Time lag estimation is a difficulty that is also common to the other classes of analyses discussed below. There are actually two sets of time lags. The first is the lag between production and consumption, during which a product is in the distribution system. The second is the lag between purchase and discard. Although rational methods for developing time lag assumptions for both kinds of lags can be developed and defended, they will necessarily rely in large part upon intuitive processes. It may be reasonably safe to assume that all packaging materials used in packaging consumer products enter the waste stream within a year of their production. It may be less safe to assume that small appliances enter the waste stream at a rate equivalent to the production output of a part year (selected by consulting product life expectancy data), or that the rate of disposal for all textiles used in clothing can be assigned a single "average" lag rate.

A second, more fundamental difficulty with the production data or input approach is the need to know not only how much of a given material is produced, but also for what it is used. Polyester fiber may be used in cordage, automobile upholstery and electric cable insulation, as well as in textiles incorporated into clothing. The nature of the use will determine whether a material ends up in automobile scrap, demolition waste, or household waste. It will also determine the lag time, which varies widely with different end-uses.

For every major component of the waste stream, it is necessary to determine the weight of material sold by its producers to all manufacturers of products or materials destined for sales to consumers. For some materials, such as glass bottles, data are readily available; for others, they are not.

Waste estimation based on production data has a significant advantage over survey-based estimates in that time series data are available on which to base a forecasting procedure. While such time series will be useful for short-range forecasts, they cannot be used for long-range estimation. Extrapolation from past production will not be a reliable indication of probable future concentrations of tinned steel, aluminum, or bimetal cans, metal foil, glass, paper, or plastic containers in the packaging of consumer products. To develop such an indication requires an independent reconciliation of the competing claims for materials that can be substituted for one another.

Studies employing econometric techniques have focused on analyzing consumer expenditure data and other economic and social variables. R.A. Richardson and J. Havlicek have published papers which suggest that such variables as household income and age structure and size of households appear to be important factors affecting the quantity and composition of solid waste, based on an analysis of data samples in Indianapolis, Indiana (29). However, the authors conclude that further research appears necessary to disaggregate waste materials and relate their quantities directly to household consumption patterns.

A detailed analysis of consumer spending patterns was carried out by URS Research Company to permit the analysis of waste generation (30,31). Two models were developed; one for the prediction of residential solid waste generation, and the other for the prediction of commercial solid waste generation. For the residential model, total retail expenditures were collected for a regional data bank that shows the 1960-61 distribution of household spending on over 700 items. Analysis of this data shows the amount spent by households on each consumer item during the period of time sampled (usually one week). The number of items purchased was then derived from the price per unit for each consumer item. From the number of items purchased and a listing of the physical weight and composition of each item, an inventory of waste materials was generated.

The commercial model is similar insofar as it used the sales of merchandise (prorated to the specific items) and the unit price per item to determine the number of items sold. It then estimates total commercial (retail activity) waste assuming a standard waste composition for each item. It has identified discarded shipping containers as a major component of commercial waste.

This model, as ultimately developed, was oriented toward a rapid throughput of materials. Standing by itself, it would not project future solid waste generation. The interim report on the project described the procedures for dealing with projections using such variables as retail expenditures, distribution of household expenditures, price-per-unit by item, and physical description of each item. An endogenous estimate for each variable was required in order for the model to produce a projection. The interim report also recommended the development of separate models to segregate those products associated with short versus long periods of resistance.

Other attempts to use forecasts of the future consumer environment to project the amounts and composition of household packaging wastes have been made by the Research Triangle Institute (32). One study used a straightforward method to estimate future packaging waste. The weight of consumer packaging per dollar of consumer expenditure (for each of 30 categories of consumer products) was determined for 1958-1970 and extrapolated linearly to 1980. Econometric projections of personal consumption expenditures were made to determine the 1980 expenditures for each product category. From the 1980 weight of packaging per dollar and estimates of 1980 expenditures, a value for the total weight of 1980 packaging was determined. This value and an estimate of the materials distribution in packaging yield the amounts of materials used in packaging in 1980 for each product category, assuming that packaging materials become solid waste within a year.

Consumer forecast-based studies constitute an important conceptual advance over the industry production studies because they take advantage of an internally consistent set of forecasts about future levels of consumption and production, and, in general, these forecasts are based upon an adequate body of time series data. However, the consumer forecast-based studies are conceptually deficient in their handling of product consumption, whether in fixed product composition estimates or in linear extrapolation of product composition change from past composition trends. Similar to the production data studies described earlier, these studies fail to deal adequately with the lag times between purchase and disposal.

An International Research and Technology Corporation study undertook to apply all of these methods to the task of forecasting the amounts, composition, and location of future (through 1980) loads of combustible wastes from all sources (20). Livestock wastes were estimated by utilizing data on manure production per animal and forecasts of future animal populations based on future consumer expenditure forecasts. Crop waste estimates were derived from data on regional crop production and on waste generation and disposition by crop. Industrial combustible wastes were forecast based on an input-output model, which customarily describes flows of materials and products in terms of dollar sales. These were converted, using price data, into flows of physical quantities. The literature was surveyed to obtain estimates of the amounts and composition of process waste and plant trash (mostly miscellaneous packaging waste) generated per pound of output, and of waste generation trends. These data were converted into waste coefficients and applied to the model's forecasts of future outputs in order to yield forecasts of industrial process wastes. The analysis was also regionalized, using data on industry locations.

Because of the lack of regional consumer purchase forecasts, no input-output analysis of household waste was attempted. Instead, household waste generation forecasts were estimated by using per capita waste production figures derived from the 1968 survey and future population distribution figures. While stopping short of applying input-output analysis to household waste prediction, this study nevertheless marked the first formulation of input-output analysis as a tool for the development of waste management policy.

Under the auspices of EPA's Municipal Environmental Research Laboratory in Cincinnati, IR&T developed a methodology using input-output techniques to estimate and forecast industry-by-industry material consumption (33). Economic input-output analysis was used to trace the flows of physical materials through analysis of purchases by every sector in the economy, adjusting them to estimate flows to the household sector. From such a base, a dynamic model was developed to show the levels of future purchases, sector by sector. By converting the values of purchases into the weights of basic material inputs, the kinds and quantities of materials embodied in the products discarded by households was inferred. The quantity and composition of household waste was forecast to 1985 using the "corrected" structure of the economy (i.e., the economy as described in terms of materials embodied in products purchased by households) as a baseline, and employing extrapolations of interindustry coefficients.

In a recent study for the Office of Solid Waste, Research Triangle Institute (RTI) used input-output techniques to estimate and forecast the weight of material required for 478 categories of consumer expenditure (34). Production data by end-use was related to the inverse matrix of the 1967 Department of Commerce input-output table which was used to develop coefficients as reasonable first approximations of future material flows and exogenous projections of personal consumption expenditures from the Bureau of Labor Statistics.

This study departs from previous efforts in its attempt to be more comprehensive in its scope, taking into account not only material flows potentially entering the household and commercial waste stream, but also flows into other disposal sites (e.g., demolition sites and junk yards). Second, this study attempts to combine the best features of materials-flow estimation procedures and input-output techniques, to provide forecasts of materials-flow in tons that are consistent with an economic model, and thereby reflect both economic growth and structural changes in the economy that have an impact on the composition of the solid waste stream (e.g., materials substitution and technological changes).

METHODOLOGY AND SCOPE

The methodology presented here combines features of the production data or materials flow estimation procedures developed by William Franklin, Fred Smith, and Frank Smith, and the input-output analysis and forecasting techniques developed by Stedman B. Noble in the IR&T household waste study for EPA, briefly described above (33). While an overview of the methodology is presented here, a more detailed description is presented in a later section.

The approach used in this study differs from the solid waste estimation procedures developed by Stedman Noble, although they also explore the economic relationships suggested by the input-output table to estimate and forecast material flows. For this study, production data was related to flows of materials to product categories defined by the sectors of an interindustry forecasting model, in order to derive estimates of material use by product category. The model was then used to forecast future material use. The need for adjustments made in the Noble study to account for price differentials in the use of materials and aggregation errors was diminished. Other adjustments to the model required in the earlier study were avoided by carefully selecting only the significant flows of materials to products for the purpose of forecasting solid waste.

Although the recent RTI study also uses a combination of input-output procedures and materials-flow analysis to estimate solid waste, it does not make the detailed analysis of the economy required to adequately differentiate among the various components of the waste stream. The inverse term does indicate the direct and indirect material requirements per dollar of final demand, but it does not adequately deal with the problems of aggregation and non-embodied material flows that are enmeshed in the coefficients of the inverse tables. Furthermore, the RTI study uses static input-output coefficients, and consequently fails to take structural changes in the economy into account. Also, since projections of consumer demand are made exogenously, forecasts of the waste stream are not internally consistent with the economic data base.

This study has the advantage of providing an internally consistent set of forecasts of consumption and production that take future trends in technological developments and materials substitution into account. The methodology does not entirely solve the problems related to using the production data and time lag estimation techniques, although the time lags were derived from published estimates. Normal distributions and step functions were applied to selected material product categories in order to estimate the quantities of materials entering the waste stream.

In this study, the flows of 14 materials to 21 product categories were analyzed for the years 1960 to 1990. The materials and products included are listed in Table 1. Each of the 21 products are categorized by their Standard Industrial Classification (SIC) as shown in Table 2. The industry sector numbers refer to the interindustry model used in making the projections, and are described later. The flows of materials and their disposition have been traced from primary manufacture, through fabrication of final products, to consumers, and finally, to the point of disposal. Estimates account for new and old scrap, amounts of new and old scrap recycled, and for diversions (i.e., "disappearance") of materials from the waste flow. Attempts were made to estimate waste generation by source as well (e.g., residential/commercial, industrial, etc.). For this purpose, waste disposals by product or material were assigned to sectors as described in Table 3. Note that some process wastes, such as sludge, slag, ash, and agricultural and mining wastes, were not included in this analysis.

TABLE 1. MATERIAL, PRODUCT, AND DISPOSAL CATEGORIES USED IN THIS STUDY

Material Categories	Product Categories	Disposal Categories
• Paper	• Newspaper	• Residential
• Paperboard	• Books, Periodicals and Other Printing Paper	• Commercial
• Plastics	• Writing and Other Fine Paper	• Industrial
• Glass	• Disposable Products	• Transport
• Aluminum	• Beverage Containers	• Construction
• Zinc	• Other Packaging and Containers	• Demolition
• Copper	• Consumer and Institutional Products	
• Lead	• Furniture and Furnishings	
• Ferrous Metals	• Apparel	
• Wood	• Footwear	
• Textiles	• Household Durables	
• Rubber	• Electrical and Electronic Products	
• Leather	• Machinery and Other Industrial Equipment	
• Concrete	• Automobiles	
	• Other Transportation Vehicles	
	• Tires and Inner Tubes	
	• Batteries	
	• Buildings and Structures	
	• Ordnance	
	• Other Industrial Applications	
	• Miscellaneous	
	• Other Components of Waste Stream	
	- Food Waste	
	- Yard Waste	

The methodology is displayed diagramatically in Figure 1. The procedure for estimating the quantity and composition of solid waste begins with estimates of economic activity generated by an adapted version of the Interindustry Forecasting Model of the University of Maryland.* The INFORUM Model makes macroeconomic projections of Gross National Product and its components - Personal Consumption Expenditures, Producers' Durable Equipment Investment, Construction Expenditures, Government Expenditures, Exports and Imports - year by year from 1971 to 1990. These final demand estimates are provided for each of the 185 product categories, encompassing agriculture, mining, manufacturing and services. Final demand projections are run through an input-output table where they are combined with interindustry (or intermediate) demands to estimate the total outputs of the 185 categories, or sectors. The coefficients of the input-output table are dynamic so that the effects of

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* A detailed description of INFORUM is contained in *1985: Interindustry Forecasts of the American Economy*, Clopper Almon, et al., Lexington Books, Lexington, Massachusetts, 1974.

TABLE 2. DEFINITION OF PRODUCT CATEGORIES

NAME	INDUSTRY SECTOR	SIC CODE	DESCRIPTION
Newspaper	52	2711	Newspaper
Books, Periodicals and Other Printing Paper	53	2721	Periodicals: Publishing
	54	2731	Books: Publishing
	57	2741	Miscellaneous Publishing
	58		
Writing and Other Fine Paper	49	2642	Envelopes
		2649	Converted Paper and Paperboard Products, NEC (i.e., stationery, notebooks, writing tablets)
		2645	Die-Cut Paper and Paperboard and Carboard
	56	2761	Manifold Business Forms
		2782	Blankbooks, Loose Leaf Binders and Devices
Disposal Products	49	2647	Sanitary Paper Products
Beverage Containers	78	3221	Glass Containers
	92	3411	Metal Cans
Other Packaging/ Containers	44	244	Wooden Containers
	49	2646	Pressed and Molded Pulp Goods
	51	265	Paperboard Containers and Boxes
	74	3079	Miscellaneous Plastic Products
	78	3221	Glass Containers
	92	3411	Metal Cans
	93	3491	Metal Shipping Barrels, Drums, Kegs and Pails

(continued)

TABLE 2 (continued)

NAME	INDUSTRY SECTOR	SIC CODE	DESCRIPTION
Other Packaging/ Containers (continued)	101	3499	Miscellaneous Fabricated Metal Products, NEC (i.e., foil, tube)
Other Consumer/Institutional Products	73	3069	Fabricated Rubber Products
	74	3079	Miscellaneous Plastic Products
	77	3172	Personal Leather Goods
	78	3229,3231	Glassware
	83	3321	Cooking Utensils, Cast Iron
	87	3361	Cooking Utensils, Cast Aluminum
	97	3461	Metal Stampings
	98	3421	Cutlery
		3423	Hand and Edge Tools
		3425	Hand Saws and Saw Blades
		3429	Hardware, NEC
	124	364	Electric Lighting and Wiring Equipment (Light Bulbs)
	126	3652	Phonograph Records
	143	3831	Optical Instruments and Lenses
	144	384	Surgical Medical and Dental Instruments and Supplies
	145	3861	Cameras, Photographic Equipment
	146	387	Watches, Clocks and Parts
	147	391	Jewelry, Silverware and Plated Metal
	148	2941-2-3	Toys
		3931	Musical Instruments
		3949	Amusement, Sporting and Athletic Goods
	149	395	Office Supplies
	150	399,396	Miscellaneous Manufacturing: Costume Jewelry and Novelties
Furniture and Furnishings	36	227	Floor Coverings

(continued)

TABLE 2 (continued)

NAME	INDUSTRY SECTOR	SIC CODE	DESCRIPTION
Furniture and Furnishings (continued)	40	239	Household Textiles
	45	251	Household Furniture
	46	252	Office Furniture
Apparel	39	23	Apparel
Footwear	73	302	Rubber Footwear
	76	314	Footwear, Exc. Rubber
Household Durables	103	3522	Lawnmowers
	116	3585	Air Conditioning Equipment
	123	363	Household Appliances
	125	365	Radio and T.V. Receiving
Electrical/Electronics	80	3264	Porcelain Electrical Supplies
	118	3611	Electrical Measuring Instruments
	119	3612-3	Transformers and Switchgear
	120	3621	Motors and Generators
	121	3622	Industrial Controls
	122	3623-4-9	Welding Apparatus and Graphic Products
	124	364	Electric Lighting and Wiring Equipment
	127	366	Communication Equipment
	128	367	Electronic Components
	130	3694	Engine Electrical Equipment
	131	3693,3699	X-Ray Equipment and Electronic Equipment
Machinery and Industrial Equipment	102	351	Engines and Turbines
	103	352	Farm Machinery

(continued)

TABLE 2 (continued)

NAME	INDUSTRY SECTOR	SIC CODE	DESCRIPTION
Machinery and Industrial Equipment (continued)	104	3531-2-3	Construction, Mining and Oilfield
	105	3534-5-6-7	Materials Handling Machinery
	106	3541	Machine Tools, Metal Cutting
	107	3542	Machine Tools, Metal Forming
	108	3544-5-8	Other Metal Working Machinery
	109	355	Special Industrial Machinery
	110	3561-4	Pumps, Compressors, Blowers, Fans
	111	3562	Ball and Roller Bearings
	112	3566	Power Transmission Equipment
	113	3565-7-9	Industrial Patterns
	114	3571-3-4	Computers and Related Machines
	115	3572-6-9	Other Office Machinery
	116	358	Service Industry Machinery
	117	359	Machine Shop Products
Automobiles	133	3711	Motor Vehicles
		3712	Passenger Car Bodies
		3714	MV Parts and Accessories
Other Transportation	132	3713	Truck and Bus Bodies
		3715	Truck Trailers
	134	372	Aircraft
	137	373	Ship and Boat Building
	138	374	Railroad Equipment
	139	375	Cycles and Parts
	140	3791	Trailer Coaches
Tires and Inner Tubes	72	3011	Tires and Inner Tubes
Batteries	129	3691	Storage Batteries
		3692	Primary Batteries

(continued)

TABLE 2 (continued)

NAME	INDUSTRY SECTOR	SIC CODE	DESCRIPTION
Buildings and Structures	41	241,242	Lumber and Wood Products
	42	2432	Veneer and Plywood
	43	2433	Millwork and Wood Products
	78	3211	Flat Glass for Windows
	79	325	Structural Clay Products
	80	3261	Plumbing Fixtures and Bathroom Accessories
	94	343	Heating Apparatus and Plumbing
	95	3441	Fabricated Structural Steel
	100	3494	Pipes, Valves, Fittings
	101	3498	
Ordnance	20	1925	Complete Guided Missile
	21	1929,1961	Ammunition
	22	1931-41-51-11-99	Other Ordnance
Other Industrial Applications			Materials Consumed in Other Materials
Miscellaneous			Other Product End Uses, Not Elsewhere Classified

Source: Office of Management and Budget, *1972 Standard Industrial Classifications*, and Clopper Almon, et al., *1985: Interindustry Forecasts of the American Economy*, Lexington Books, Lexington, Massachusetts, 1974. Compiled by International Research and Technology Corporation.

TABLE 3. DESCRIPTION OF SOLID WASTE SOURCE CATEGORIES USED IN THIS REPORT

Post-Consumer Residential Wastes -

This category includes product wastes originating in private households, including bulky items such as household appliances, as well as tires. The term "post-consumer" refers to old or obsolete final products or user discards as distinct from the processing residuals of industrial refining or manufacturing activities.

Post-Consumer Commercial Wastes -

This category includes wastes emanating from office buildings, restaurants, hospitals, and all other commercial trade and service establishments. This category also includes bulky items (e.g., appliances) and tires from the commercial/institutional sector. Post-consumer refers to old or obsolete final products as distinguished from industrial process wastes.

Transport Sector Wastes -

This category includes product category wastes (except tires) from automobiles and all other modes of transportation, i.e., trucks, ships, airplanes, railroad, and transport equipment) as well as batteries from all modes of transportation.

Industrial Wastes -

This category includes two distinct types of solid waste: obsolete and current. Obsolete waste includes plant, machinery and other equipment previously used in the manufacture of products. Prompt scrap or new scrap is material waste generated during the fabrication process and is usually marketed or sometimes recycled within the plant.* Prompt scrap is forecast separately from the total scrap material created during the fabrication process.

The total industrial waste category includes only the material generated during the manufacture of products and does not include sludge, ash, mining or agriculture wastes.

Construction Wastes -

This category includes all wastes from various materials during the construction of buildings and structures.

Demolition Wastes -

This category includes all wastes generated during the destruction of various buildings and structures.

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* Scrap recycled within a plant is usually referred to as home scrap (in-house) or mill revert.

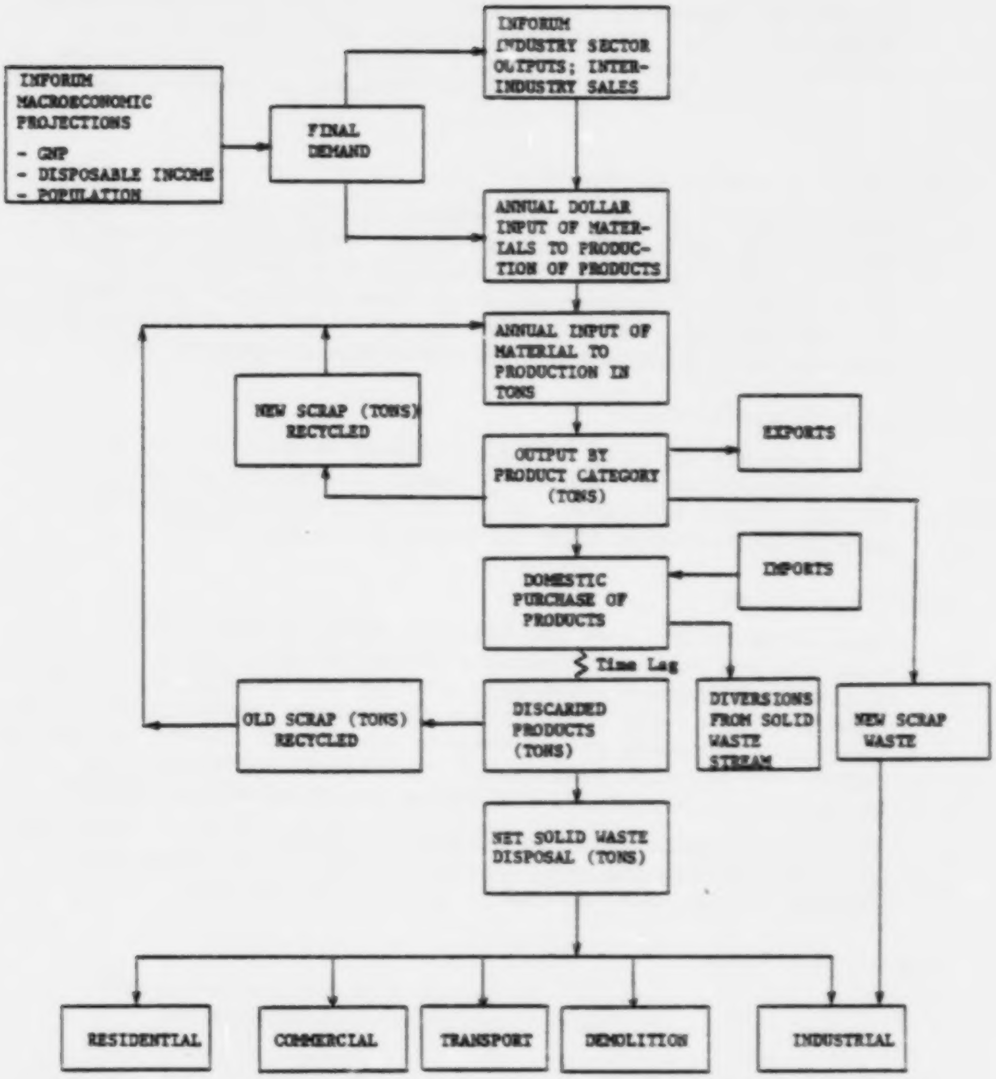

INFORUM MACROECONOMIC PROJECTIONS
- GNP
- DISPOSABLE INCOME
- POPULATION
FINAL DEMAND
INFORUM INDUSTRY SECTOR OUTPUTS; INTER-INDUSTRY SALES
ANNUAL DOLLAR INPUT OF MATERIALS TO PRODUCTION OF PRODUCTS
ANNUAL INPUT OF MATERIAL TO PRODUCTION IN TONS
NEW SCRAP (TONS) RECYCLED
OUTPUT BY PRODUCT CATEGORY (TONS)
EXPORTS
IMPORTS
DOMESTIC PURCHASE OF PRODUCTS
Time Lag
OLD SCRAP (TONS) RECYCLED
DISCARDED PRODUCTS (TONS)
DIVERSIONS FROM SOLID WASTE STREAM
NEW SCRAP WASTE
NET SOLID WASTE DISPOSAL (TONS)
RESIDENTIAL
COMMERCIAL
TRANSPORT
DEMOLITION
INDUSTRIAL

Figure 1. Conceptual flow diagram of the IR&T Solid Waste/Recycling Model.

Source: International Research and Technology Corporation.

trends in technological innovation, materials substitution, relative prices and tastes are accounted for in the model itself.

From the INFORUM projection, the inputs of materials to product categories in constant dollar terms over time are extracted for use in estimating solid waste generation. The dollar flows are translated into physical flows on the basis of historical data (from 1960 to 1971) described in the appendix to this report. The physical flows by material type are then adjusted to account for new scrap generation (recycled amounts are returned to the input mode, unrecycled new scrap is included in the industrial waste category) and exports of products, to estimate the amount of material embodied in products produced domestically. Imports of products are included to estimate apparent domestic consumption by product. Diversions of products from the waste stream are removed at this point.

Each product has an associated average product life assumption. After appropriate time lags (estimated by normal distribution or step functions), products are disposed of in the relevant waste stream. Old scrap that is salvaged is returned to the material input mode, and the remainder constitutes net solid waste. This component is disaggregated to the consuming sectors, as described previously. Note, however, that construction wastes, as the diagram is presented, are included in the new scrap recycled and new scrap waste modes, since structures are considered as an end-use product.

Figure 2 depicts the flow of materials through the economy, as conceptualized in the IR&T model. Primary, secondary and imported materials are combined to produce finished materials. The secondary materials included in this stage are obtained from old scrap and recycled new scrap. Finished materials are used in the production of products, and the scrap from production is discarded or recycled. Imported finished products are included (exports are removed, as are diversions from the solid waste stream) and the products are purchased by consumers. After a time lag, products are discarded. Some materials from these products are recycled; the remainder, along with new scrap waste, constitutes total net waste disposal.

The mathematical formulation uses a materials/product history file as input. This file provides estimates of the use of each material in the manufacture of products, from 1960 to 1971, maintained in matrix form. All historical materials/product data used by the model are provided in an appendix to this report. However, the data for 1971 are displayed in Table 4 as an example. The data is manipulated through the model, using estimates of the fraction of each material flowing to each product category that is new scrap, and adjustments to account for product imports and exports, to arrive at estimates of net material consumption by product category. For example, the flows of aluminum to each product category and adjustments for 1971 are displayed in Figure 3. Data for all material flows in 1971 are provided in the aforementioned appendix. Other assumptions regarding average product life, the disposition of wastes by consuming sector, and the extent of recycling by material and product, are then used to estimate net solid waste generation.

In forecast years, alternative assumptions regarding overall economic growth, trends in materials substitution and trends in technology change are

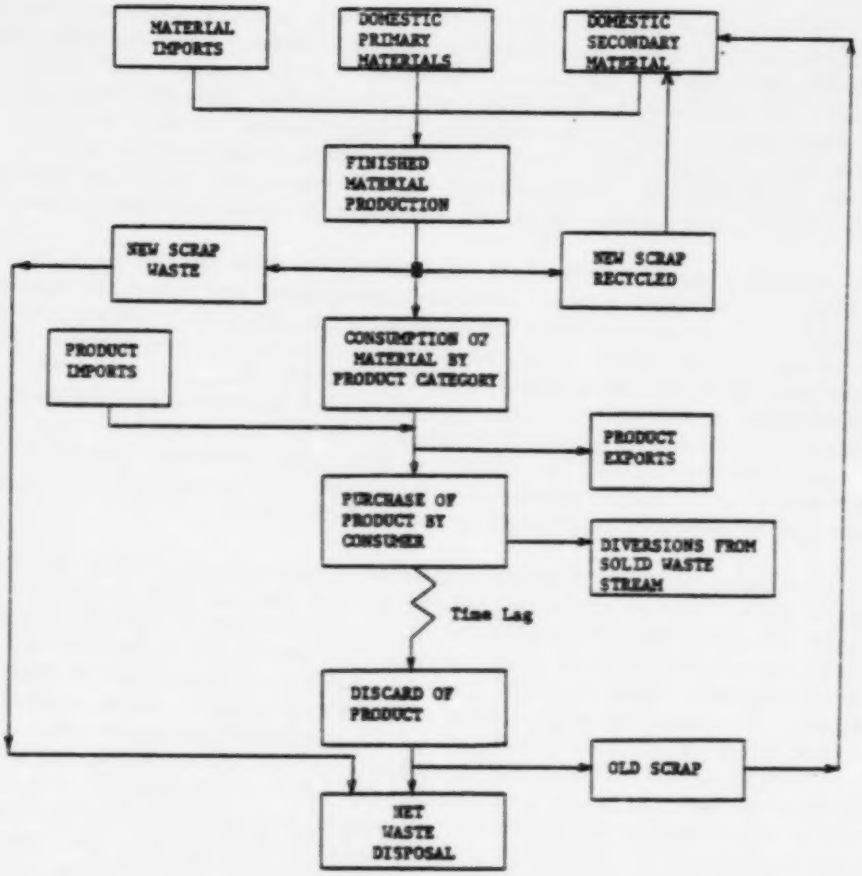

MATERIAL IMPORTS
DOMESTIC PRIMARY MATERIALS
DOMESTIC SECONDARY MATERIAL
FINISHED MATERIAL PRODUCTION
NEW SCRAP WASTE
NEW SCRAP RECYCLED
PRODUCT IMPORTS
CONSUMPTION OF MATERIAL BY PRODUCT CATEGORY
PRODUCT EXPORTS
PURCHASE OF PRODUCT BY CONSUMER
DIVERSIONS FROM SOLID WASTE STREAM
Time Lag
DISCARD OF PRODUCT
OLD SCRAP
NET WASTE DISPOSAL

Figure 2. Material flows in the IR&T Solid Waste/Recycling Model.

Source: International Research and Technology Corporation.

TABLE 4. MATERIAL/PRODUCT MATRIX FOR 1971 (Thousand Metric Tons)

	PRODUCT CATEGORIES										
Material	**Newspaper**	**Books & Periodicals**	**Writing Paper**	**Disposables**	**Beverage Containers**	**Other Packaging**	**Consumer/ Insti- tutional Products**	**Furniture**	**Apparel**	**Footwear**	**Household Durables**
Aluminum	0	0	0	0	417	279	245	67	0	0	134
Copper	0	0	0	0	0	0	135	0	0	0	71
Ferrous Metals	0	0	0	0	1404	6546	1698	1993	0	0	3691
Lead	0	0	0	0	0	56	24	0	0	0	0
Zinc	0	0	0	0	0	0	151	0	0	0	29
Glass	0	0	0	0	5775	4336	2159	0	0	0	268
Leather	0	0	0	0	0	0	87	13	38	367	0
Plastics	0	0	0	0	0	2214	1135	422	0	0	257
Rubber	0	0	0	0	0	0	37	28	52	157	169
Textiles	0	0	0	12	0	0	473	1515	2126	30	0
Wood	0	0	0	0	0	6512	1102	4871	0	0	0
Paper	9103	6702	3518	3307	0	4710	321	0	0	0	0
Paperboard	0	42	0	0	0	20237	347	0	0	40	0

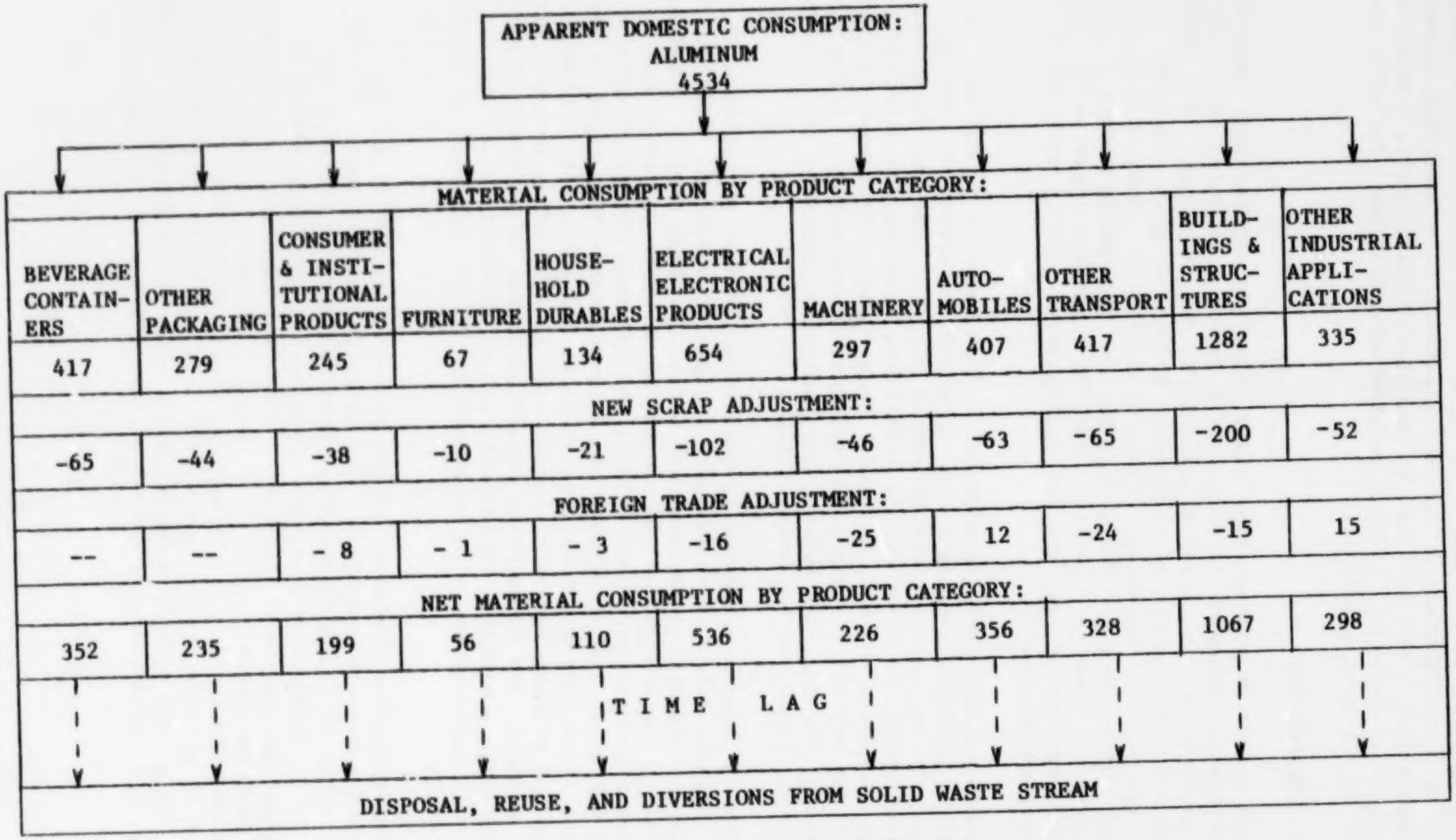
(continued)

Source: International Research and Technology Corporation, September 1978

TABLE 4 (continued)

Material	PRODUCT CATEGORIES									
	Electronics	Machinery	Automobiles	Other Transportation	Tires	Batteries	Construction	Ordnance	Other Industrial Applications	Miscellaneous
Aluminum	654	297	407	417	0	0	1282	0	335	0
Copper	1385	314	190	59	0	0	457	89	0	0
Ferrous Metals	6301	13393	25557	5994	0	0	35910	950	0	4419
Lead	51	67	24	4	0	688	102	89	349	0
Zinc	122	81	233	114	0	0	429	0	0	0
Glass	664	0	992	102	0	0	1256	0	0	0
Leather	0	1	0	0	0	0	0	0	0	0
Plastics	540	205	438	183	0	0	1609	0	1016	98
Rubber	20	180	248	34	1796	0	0	0	0	0
Textiles	12	39	24	20	283	0	0	0	168	0
Wood	0	798	0	440	0	0	45187	0	0	0
Paper	23	0	0	0	0	0	0	0	0	0
Paperboard	18	0	52	0	0	0	5648	0	0	0

Source: International Research and Technology Corporation, September 1978.



APPARENT DOMESTIC CONSUMPTION:
ALUMINUM
4534

	BEVERAGE CONTAINERS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	HOUSEHOLD DURABLES	ELECTRICAL ELECTRONIC PRODUCTS	MACHINERY	AUTOMOBILES	OTHER TRANSPORT	BUILDINGS & STRUCTURES	OTHER INDUSTRIAL APPLICATIONS
MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	417	279	245	67	134	654	297	407	417	1282	335
NEW SCRAP ADJUSTMENT:	-65	-44	-38	-10	-21	-102	-46	-63	-65	-200	-52
FOREIGN TRADE ADJUSTMENT:	--	--	- 8	- 1	- 3	-16	-25	12	-24	-15	15
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	352	235	199	56	110	536	226	356	328	1067	298

TIME LAG

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

Source: International Research and Technology Corporation.

Figure 3. Material flow diagram of aluminum in 1971 (thousand metric tons).

made within the economic forecasting model. These assumptions dictate the growth in demand for products and their material composition. The starting point for the analysis of the impact of all of these factors on the quantity and composition of solid waste is the establishment of a Reference Scenario, or set of assumptions, that can then be adjusted in alternative scenarios to perform sensitivity analyses. Five scenarios were developed for this study, as described in the next section.

SUMMARY AND CONCLUSIONS

The five scenarios suggest that waste reduction and resource recovery can be significantly enhanced by encouraging certain technological changes, materials substitution, increased product life, and recycling. The trends in materials use, and the mix of forecasted product demands, indicate that the composition of solid waste may change dramatically. Most notable are the declining shares of steel and glass, and the increasing shares of aluminum and plastics. Despite expected trends in materials substitution and resource recovery initiatives, the per capita waste load is expected to continue to increase nationally.

The economic model projects especially high rates of growth for industries supplying plastics, concrete, and aluminum. A review of past and current trends in the use of these materials suggests that the projected growth is reasonable. For two of the materials, plastics and concrete, little or no recycling has been assumed. Consequently, the share of these materials in the net solid waste load increases substantially. Aside from these materials, however, the bulk of the waste load continues to be comprised of steel, paper and paperboard, glass and wood.

The national trends suggested by the scenarios must be viewed with caution by regional solid waste managers and policy analysts. Past and projected regional consumption patterns and materials usage must be taken into consideration in the design and implementation of waste reduction and resource recovery techniques. Nonetheless, the national trends do provide indicators of the types and directions of regional trends that might be expected. National trends and known effects of state and local initiatives to reduce waste and promote recovery, can be used in evaluating proposed programs. For example, the assumptions regarding trends in recovery of materials from beverage containers nationally, can be adjusted to account for state and local initiatives, such as those in Vermont, Oregon, and Fairfax County, Virginia.

The five scenarios presented in the next section depict a range of plausible future solid waste loads. The estimates of new wastes in 1990 vary from a total of 295 million metric tons assuming increased product lifetimes, to 341 million metric tons assuming no technology change or materials substitution. The projected trends in post-consumer recycling can reduce the 1990 net waste load by five percent. A modest increase in these initiatives can reduce the load by an additional one percent, for a total reduction of 20 million metric tons by 1990. It is clear that the extent of technology change and materials substitution, the effectiveness of recycling initiatives, and the average lifetimes of future products, can substantially affect the quantity and composition of the waste generated by our society. The estimates presented in this study are substantiated to a great extent by estimates derived in previous studies. Comparisons of these estimates, presented in Section 3, indicate areas in which this study provides significant improvements in the data base and methodologies used to manipulate solid waste data.

SECTION 2

THE FORECASTS

Five scenarios, or sets of assumptions, were developed to estimate the impacts of technology change and materials substitution, recycling initiatives, and average product lifetimes on the future quantity and composition of solid waste. The first scenario, called the Reference Scenario, provides a basis for performing this analysis. The assumptions of the Reference Scenario depict a future in which past and current trends in economic growth, materials substitution, and recycling rates are extrapolated in a more or less business-as-usual context. In four alternate scenarios, one or more of the categories of assumptions are either relaxed or emphasized. A Constant Technology Scenario employs the economic growth assumptions of the Reference Scenario, but assumes no change from the mix of technologies and materials used to manufacture products in 1971. The impact of recycling is addressed in two scenarios; one in which the recycling rates for 1977 are held constant through 1990, and another in which the assumed recycling rates are increased ten percent over Reference Scenario assumptions for each material and product category and each forecast year. Finally, a fifth scenario was developed in which the average product life assumptions of the Reference Scenario were increased ten percent. Herewith are more detailed descriptions of the scenarios, and their results.

THE REFERENCE SCENARIO

The projections of solid waste flows are based on estimates of future economic activity generated by the INFORUM model. The model provides highly detailed estimates of interindustry transactions in response to purchases of particular end-use products. These final demand purchases are estimated on the basis of assumptions regarding growth in income and population, interest rates, and relative prices. Estimates of aggregate final demand - or Gross National Product - and its components are shown in Table 5.

As can be seen, Gross National Product is assumed to grow at its long-term average rate of 3.4 percent per year, supported by continued moderate increases in productivity. This productivity growth results in part from the farily rapid growth in producers' durable equipment investment. The combination of growth in productivity and slowing growth in the size of the labor force yields a declining unemployment rate.

Nearly two-thirds of GNP is comprised of personal consumption expenditures, as has generally been the case over the past thirty years. It is

TABLE 5. REFERENCE SCENARIO GROSS NATIONAL PRODUCT SUMMARY
(Billions of 1971 Dollars Except as Noted)

Components of GNP and Exogenous Assumptions	1971	1980	1990	Average Annual Percentage Growth 1971-1990
Gross National Product	1063.4	1387.0	2021.4	3.4
Personal Consumption Expenditures	668.2	869.0	1328.8	3.7
Durable Goods	63.3	82.3	128.1	3.8
Non-Durable Goods	148.9	176.0	236.8	2.5
Services	281.0	393.0	641.9	4.4
Gross Private Domestic Investment	160.0	212.8	318.1	3.7
Structures	87.9	97.9	139.1	2.4
Producers' Durable Equipment	65.7	105.3	161.7	4.9
Net Exports	1.6	23.0	22.6	15.0
Exports	65.6	112.7	166.5	5.0
Imports	- 64.0	- 89.7	- 143.9	4.4
Government Purchases	233.7	282.2	352.0	2.2
Productivity ($1000 Per Employee)	13.0	14.4	18.3	1.8
Employed Persons (Millions)	81.7	96.6	110.6	1.6
Disposable Per Capita Income (58$)*	2566.0	3307.7	4790.6	3.3
Population (Millions)*	207.1	222.8	245.9	.9
Labor Force (Millions)*	86.9	101.8	118.7	1.7
Civilian Unemployment Rate (%)*	5.9	5.6	4.7	-1.2

* Exogenous Assumptions

Source: Compiled by International Research and Technology Corporation from Modified INFORUM Projections.

intersting to note, however, that consumer spending is expected to shift away from non-durable goods in favor of durables and, especially services. This shift is likely to have significant impacts on the quantity and composition of solid waste. The economic model provides disaggregate forecasts for each component of GNP, which are then used to estimate the output levels for each of 185 industries. Projected outputs for selected industries are shown in Table 7. As can be seen, relatively rapid growth is forecast for the new and maintenance construction industries, which draw on the outputs of some supplying industries shown, notable cement, concrete and gypsum. Very rapid growth is projected for the plastic materials and resins industry, as plastics are increasingly used in place of metals, glass, and paper in numerous products. Growth in the output of pulp mills is also rapid, spurred by continued substitution of paper in packaging and increased use of paper and paperboard in structural applications. Sluggish growth is forecast for the steel industry, due in large part to substitutions of aluminum in automobiles and beverage containers.

To indicate the types of material substitutions occurring in the Reference Scenario, Table 6 displays trends in selected input-output coefficients for two industries: motor vehicles and household furniture. In a number of cases, large rates of substitution are assumed, such as plastics and aluminum in place of steel in automobiles, and plastics and aluminum in place of steel and wood in furniture.

TABLE 6. REFERENCE SCENARIO TRENDS OF FINAL DEMAND IN SELECTED MATERIAL INPUTS PER DOLLAR, 1971-1990.* (1971 = 1.00)

Buying Sector: Motor Vehicles	
Selling Sector	1990 Index Value
Plastic Materials and Resins	2.35
Steel	.40
Aluminum	2.00
Buying Sector: Household Furniture	
Selling Sector	1990 Index Value
Lumber and Wood Products	.75
Plastic Materials and Resins	1.44
Glass	1.00
Steel	.79
Aluminum	1.22

* Based on the inverse of the Input-Output Matrix.

Source: Compiled by International Research and Technology Corporation from outputs of a modified INFORUM Model.

The economic projections are combined with the historical materials-flow data and assumptions regarding new scrap fractions, recycling rates and aver-

TABLE 7. REFERENCE SCENARIO OUTPUTS OF SELECTED INDUSTRIES
(Millions of 1971 Dollars)

Industry Number and Name		1971	1980	1990	Average Annual Percentage Growth 1971-1990
8	Forestry and Fishery Products	2255	2971	3974	3.0
11	Iron Ore	1349	2128	2536	3.4
12	Copper Ore	1471	1826	2319	2.4
13	Other Nonferrous Ores	1005	1237	1833	3.2
16	Stove and Clay Mining	2426	3864	5649	4.5
18	New Construction	45192	66422	90123	3.7
19	Maintenance Construction	16994	23522	35484	4.0
41	Lumber and Wood Products	9403	11427	15727	2.7
47	Pulp Mills	1123	1786	2746	4.8
62	Plastic Materials and Resins	3768	7644	13521	7.0
73	Rubber Products	3665	5692	7749	4.0
75	Leather Products	956	1068	1298	1.6
78	Glass	5120	7005	9458	3.3
81	Cement, Concrete, Gypsum	8243	16870	29210	6.9
83	Steel	31263	40046	45996	2.1
84	Copper	6873	8971	11650	2.8
85	Lead	536	595	915	2.9
86	Zinc	420	610	806	3.5
87	Aluminum	6751	11459	19510	5.7
92	Metal Cans	3888	4783	6643	--
133	Motor Vehicles	60163	75865	111380	3.3

Source: Compiled by International Research and Technology Corporation from modified INFORUM projections.

age product life, as described in Section 1. The new scrap fractions and recycling rates assumed for the Reference Scenario are summarized in Tables 8 and 9. For cases in which data exist, separate new scrap fractions have been employed. In other cases, the same fraction was used for all product categories. High recycling rates are assumed for most new scrap materials; exceptions include rubber and leather.

TABLE 8. REFERENCE SCENARIO. ASSUMPTIONS FOR NEW SCRAP AND NEW SCRAP RECYCLED

Material	New Scrap Fraction[1]	Fraction of New Scrap Recycled[2]
Paper	*	.870
Paperboard	*	.870
Plastics	.049	.580
Glass	*	1.00
Aluminum	.156	.840
Zinc	.146	.680
Copper	.310	.995
Lead	*	.990
Ferrous Metals	*	1.00
Wood	*	.740
Textiles	*	.600
Rubber	*	.250
Concrete	.000	1.00
Leather	.150	.000

* See Table 9.

[1] Fraction of total in-house scrap.

[2] Fraction of in-house scrap that is recycled for re-use.

Source: Compiled by International Research and Technology Corporation. See Appendix for detailed source listing.

Recycling rates for old scrap by material and product category are presented in detail in the appendix. However, a summary of the assumed recycling rates, based on outputs of the model, is provided in Table 10. The table shows the percent of all materials recovered from both new and old scrap. As can be seen, the rates are fairly high. By 1990, 29 percent of all paper, 58 percent of the aluminum, and 62 percent of the steel entering the waste stream is recycled. The high amounts of aluminum and steel are recovered primarily from automobiles.

TABLE 9. SOLID WASTE RECYCLING MODEL REFERENCE SCENARIO, NEW SCRAP GENERATION BY PRODUCT CATEGORY FOR SELECTED MATERIALS

	MATERIAL							
Product Category	Paper	Paperboard	Glass	Wood	Textiles	Rubber	Ferrous Metals	Lead
Newspapers	.025							
Books & Periodicals	.150	.170						
Writing Paper	.061							
Disposables	.050				.050			
Bev. Containers			.047				.120	
Other Packaging	.050	.136	.047	.235			.120	.100
Cons/Inst. Prod.	.050	.170	.068	.600	.050	.050	.200	.100
Furniture				.600	.050	.050	.200	
Apparel					.100	.050		
Footwear		.170			.050	.050		
Household Durables			.080			.050	.200	
Elect/Electronics	.050	.170	.068		.050	.050	.200	.100
Machinery				.300	.050	.050	.200	.100
Automobiles		.170	.133		.050	.050	.200	.100
Other Transportation			.133	.100	.050	.050	.200	.100
Tires					.050	.030		
Batteries								.100
Construction		.065	.138	.100			.200	.100
Ordnance							.200	.100
Other Indust. Appl.					.050		.000	.000
Miscellaneous							.200	

Source: Compiled by International Research and Technology Corporation. See Appendix for detailed source listing.

TABLE 10. REFERENCE SCENARIO, POST-CONSUMER RECYCLING ASSUMPTIONS*
1971 AND 1990

Material	Percent Recovered 1971	 1990
Paper and Paperboard	23.2	29.0
Glass	9.9	12.3
Metal	52.5	61.1
Ferrous	52.8	61.8
Aluminum	44.8	57.6
Other	51.1	61.3
Plastics	6.7	5.9
Rubber and Leather	5.0	9.5
Textiles	56.7	54.3
Wood	18.8	21.2
Concrete	0.0	0.0
Total Non-Food	27.7	28.3
Food Waste	0.0	0.0
Total Product Waste	25.6	26.7
Yard Waste	0.0	0.0
TOTAL	23.7	24.9

* The figures presented here are composites for materials recovered from 21 different product categories.

Source: Compiled by International Research and Technology Corporation.

Product lifetime assumptions for all scenarios are shown in Table 11. Six of the product categories have an average life of under one year, including all paper products and beverage containers. In the Reference Scenario an average life of fifty years is assumed for buildings and structures, while automobiles, furniture, and household durables have ten-year average lifetimes. As with the new scrap fractions and recycling assumptions, the product lifetime assumptions can be changed to develop alternative solid waste scenarios.

Net solid waste projections of the Reference Scenario are shown in Tables 12, 13, and 14. As can be seen, the total waste load is projected to grow at a rate of 2.42 percent per year, considerably slower than GNP, but faster than population. As would be expected, the highest growth rates are projected for materials with low recycling potential, namely concrete, plastics, rubber and textiles. Continued increases in the use of aluminum in place of other materials results in fairly rapid growth in the amount of aluminum in the waste load. Conversely, the quantity of ferrous metals in the waste load grows very slowly as a result of substitutions and high resource recovery rates. Shares of paper and paperboard in the waste load decline

TABLE 11. PRODUCT LIFETIME ASSUMPTIONS FOR EACH SCENARIO FOR 1990

Product Category	Reference and Other Scenarios	Increased Product Lifetime Scenario*
Newspaper	< 1	< 1
Books, Periodicals & Other Printing Paper	< 1	< 1
Writing & Other Fine Paper	< 1	< 1
Disposable Products	< 1	< 1
Beverage Containers	< 1	< 1
Other Packaging & Containers	< 1	< 1
Consumer & Institutional Products	7	7.7
Furniture & Furnishings	10	11
Apparel	4	4.4
Footwear	2	2.2
Household Durables	10	11
Electrical & Electronic Products	15	16.5
Machinery & Other Industrial Equipment	20	22
Automobiles	10	11
Other Transportation Vehicles	20	22
Tires	5	5.5
Batteries	3	3.3
Buildings & Structures	50	55
Ordnance	5	5.5
Other Industrial Applications	2	2.2
Miscellaneous	5	5.5

Source: Compiled by International Research and Technology Corporation. Detailed references are provided in the Appendix.

* Average product lifetime assumed to be 10% longer than in Reference Scenario, except for products with assumed lifetimes of one year or less.

TABLE 12. REFERENCE SCENARIO PROJECTIONS OF NET SOLID WASTE DISPOSAL BY MATERIAL, 1971-1990 (Million Metric Tons)

Material	1971	1976	1980	1990	Avge.Annual % Growth 1971-1990
Aluminum	1.17	1.73	1.94	2.39	3.83
Concrete, Masonry	43.02	53.87	64.50	101.15	4.60
Copper	1.06	1.11	1.22	1.38	1.40
Ferrous Metals	35.02	37.60	37.91	36.87	.27
Glass	10.98	12.98	14.67	18.54	2.80
Lead	.32	.38	.31	.33	.16
Leather	.55	.61	.59	.84	2.25
Paper	18.70	18.47	20.90	28.50	2.24
Plastics	3.22	4.36	5.94	10.27	6.29
Rubber	1.73	2.21	2.46	4.29	4.90
Textiles	1.38	1.99	2.20	3.48	4.99
Wood	31.69	32.89	34.79	37.32	.86
Zinc	.69	.82	.81	.87	1.23
Paperboard	16.40	16.71	18.54	24.59	2.15
TOTAL NON-FOOD RECOVERY	165.93	185.73	206.78	270.82	2.61
Food Waste	18.67	19.42	20.09	22.10	.89
TOTAL PRODUCT RECOVERY	184.60	205.15	226.87	292.92	2.46
Yard Waste	20.37	23.02	25.12	29.84	2.03
TOTAL	204.97	228.17	251.99	322.76	2.42

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January 1979.

TABLE 13. REFERENCE SCENARIO PROJECTIONS OF NET SOLID WASTE DISPOSAL BY PRODUCT CATEGORY, 1971-1990 (Million Metric Tons)

Product Categories	1971	1976	1980	1990	Avge.Annual % Growth 1971-1990
Newspapers	6.62	6.23	6.47	9.11	1.69
Books, Periodicals	4.43	4.36	5.25	6.96	2.41
Writing/Other Fine Paper	2.40	2.70	3.52	5.71	4.67
Disposable Products	.78	.74	.93	1.32	2.81
Beverage Containers	6.81	8.03	7.84	7.03	.17
Other Packaging	35.08	34.94	38.18	45.11	1.33
Consumer/Inst. Products	4.16	5.68	7.14	10.52	5.00
Furniture & Furnishings	3.27	3.84	4.15	4.78	2.02
Apparel	.67	.82	.87	1.51	4.37
Footwear	.53	.71	.64	.98	3.29
Household Durables	2.28	3.02	3.44	4.75	3.94
Electrical/Electronic Prod.	4.10	4.68	6.10	6.74	2.65
Machinery/Indust. Equip.	8.05	8.35	8.57	9.55	.90
Automobiles	3.29	4.42	4.00	4.13	1.20
Other Transportation	1.13	1.17	1.07	1.10	-.14
Tires & Inner Tubes	1.12	1.63	1.73	3.10	5.50
Batteries	.13	.17	.11	.12	-.42
Buildings & Structures	74.09	86.31	97.96	137.58	3.31
Ordnance	.38	.53	.34	.30	-1.24
Other Industrial Appl.	—	—	—	—	—
Miscellaneous	2.72	3.53	3.72	4.33	2.48
New Scrap	3.86	3.89	4.75	6.08	2.42
TOTAL NON-FOOD RECOVERY	165.90	185.75	206.78	270.81	2.61
Food Waste	18.67	19.42	20.09	22.10	.89
TOTAL PRODUCT RECOVERY	184.57	205.17	226.87	292.91	2.46
Yard Waste	20.37	23.02	25.12	29.84	2.03
TOTAL	204.94	228.19	251.99	322.75	2.42

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation.

TABLE 14. REFERENCE SCENARIO PROJECTIONS OF NET SOLID WASTE GENERATION BY MATERIAL AND SECTOR (Million Metric Tons)

Material and Source	1971	1976	1980	1990
Aluminum	1.17	1.73	1.94	2.39
Res/Com	.77	1.15	1.24	1.42
Industrial	.17	.21	.28	.45
Transportation	.19	.32	.35	.41
Demolition	.04	.05	.07	.11
Concrete, Masonry	43.02	53.87	64.50	101.15
Demolition	43.02	53.87	64.50	101.15
Copper	1.06	1.11	1.22	1.38
Res/Com	.45	.52	.65	.75
Industrial	.22	.20	.18	.17
Transportation	.13	.13	.14	.23
Demolition	.27	.26	.25	.23
Ferrous Metals	35.02	37.60	37.91	36.87
Res/Com	16.91	18.07	19.25	18.28
Industrial	7.61	8.00	7.93	8.54
Transportation	2.82	3.43	2.40	.97
Demolition	7.69	8.10	8.33	9.08
Glass	10.98	12.98	14.67	18.54
Res/Com	10.26	12.10	13.59	16.94
Industrial	—	—	—	—
Transportation	.56	.69	.86	1.28
Demolition	.16	.19	.22	.32
Lead	.32	.38	.31	.33
Res/Com	.06	.07	.04	.03
Industrial	.03	.04	.04	.07
Transportation	.14	.19	.13	.14
Demolition	.10	.09	.09	.09
Leather	.55	.61	.59	.84
Res/Com	.47	.54	.50	.72
Industrial	.08	.07	.09	.12
Paper	18.70	18.47	20.90	28.50
Res/Com	18.46	18.20	20.60	28.09
Industrial	.24	.27	.30	.41

(continued)

TABLE 14 (Continued)

Material and Source	1971	1976	1980	1990
Plastics	3.22	4.36	5.94	10.27
Res/Com	2.95	3.90	5.20	8.36
Industrial	.18	.23	.32	.63
Transportation	.08	.22	.42	1.25
Demolition	.01	.00	.00	.03
Rubber	1.73	2.21	2.46	4.29
Res/Com	1.42	1.84	1.98	3.58
Industrial	.17	.19	.25	.35
Transportation	.14	.18	.24	.36
Textiles	1.38	1.99	2.20	3.48
Res/Com	1.21	1.81	1.95	3.13
Industrial	.15	.15	.21	.31
Transportation	.02	.03	.03	.04
Wood	31.69	32.89	34.79	37.32
Res/Com	6.77	7.25	7.93	8.20
Industrial	2.93	2.85	3.42	4.01
Transportation	.32	.35	.36	.36
Demolition	21.67	22.44	23.08	24.75
Zinc	.69	.82	.81	.87
Res/Com	.20	.28	.24	.27
Industrial	.10	.12	.14	.19
Transportation	.12	.18	.21	.26
Demolition	.27	.25	.22	.15
Paperboard & Construction	16.40	16.71	18.54	24.59
Res/Com	15.07	15.19	16.81	22.20
Industrial	.42	.44	.49	.69
Transportation	.03	.04	.04	.05
Demolition	.89	1.04	1.19	1.66
Total, All Materials	165.97	185.74	206.76	270.83
Res/Com	75.00	80.92	89.98	111.97
Industrial	12.30	12.77	13.65	15.94
Transportation	4.55	5.76	5.18	5.35
Demolition	74.12	86.29	97.95	137.57

Note: Totals for materials may not be the same due to rounding.

Source: International Research and Technology Corporation.

only slightly over the forecast period.

Demolition activities are the source of a large fraction of the solid waste generated in the projections. This sector accounts for all of the concrete, almost 25 percent of the steel, and two-thirds of the wood in the 1990 net solid waste load. The residential and commercial sector is the next largest contributor, accounting for 60 percent of the aluminum, more than half of the steel and copper, and almost all of the glass, paper, textiles, and paperboard. High resource recovery from scrap motor vehicles results in relatively small contributions by the transportation sector.

Projections of the quantities of materials recycled are displayed in Tables 15 and 16. Over half of the total quantity of recycled materials is accounted for by recovered ferrous metals. Recycled aluminum triples over the forecast horizon, while recycling of most other materials more than doubles. No recycling is assumed for concrete, leather, food and yard wastes. Most of the recovered materials are from new scrap (49 percent) and automobiles (14 percent).

The Reference Scenario suggests that total net solid waste per capita will continue to increase as a result of continued growth by the economy. However, because of materials substitution and resource recovery initiatives the growth in solid waste will be significantly lower than growth in GNP. These indicators are displayed in Table 17. Solid waste per dollar of GNP is projected to decline at a rate of 0.9 percent per year, and slow rates of growth are estimated for solid waste per capita.

The Reference Scenario provides an analytical framework for addressing the impacts of factors affecting the quantity and composition of solid waste. The impacts of technology change, materials substitution, recycling rates, and average product lifetime are estimated in four alternative scenarios, presented below.

IMPACTS OF TECHNOLOGY CHANGE AND MATERIALS SUBSTITUTION

The results of the Reference Scenario indicate that much of the reduction in future net solid waste per unit of final demand can be attributed to the substitution of lighter materials in the manufacture of final products, and to the changing pattern of final demands. The latter is demonstrated by higher growth in consumer spending on services, primarily at the expense of spending on nondurable goods. To analyze the impacts of materials substitution and technology change on solid waste, a scenario called Constant Technology was formulated. For this scenario, the economic framework and the new scrap, recycling, and product life assumptions of the Reference Scenario were employed, but no changes in the mix of materials and processes used in the manufacture of products were assumed from 1971 on. That is, the input-output coefficients of the economic model were held constant at their 1971 values. Comparisons of the net solid waste and recycled materials projections of each scenario for 1980 and 1990 are given in Tables 18 through 25.

TABLE 15. REFERENCE SCENARIO PROJECTIONS OF RECYCLED SOLID WASTE BY MATERIAL, 1971-1990 (Million Metric Tons)

Material	1971	1976	1980	1990
Aluminum	.95	1.23	1.78	3.24
Concrete, Masonry	0	0	0	0
Copper	1.35	1.37	1.68	2.18
Ferrous Metals	39.21	42.32	50.00	59.69
Glass	1.20	1.40	1.69	2.59
Lead	.53	.73	.67	1.39
Leather	0	0	0	0
Paper	4.89	4.95	5.70	9.86
Plastics	.23	.28	.37	.65
Rubber	.12	.18	.20	.54
Textiles	1.81	2.31	2.59	4.15
Wood	7.34	7.13	8.66	10.04
Zinc	.28	.31	.37	.52
Paperboard	5.71	6.66	7.45	11.89
TOTAL NON-FOOD RECOVERY	63.62	68.87	81.16	106.74
Food Waste	0	0	0	0
TOTAL PRODUCT RECOVERY	63.62	68.87	81.16	106.74
Yard Waste	0	0	0	0
TOTAL	63.62	68.87	81.16	106.74

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation.

TABLE 16. REFERENCE SCENARIO PROJECTIONS OF RECYCLED SOLID WASTE BY PRODUCT CATEGORY, 1971-1990 (Million Metric Tons)

Product Category	1971	1976	1980	1990
Newspapers	1.98	1.86	2.16	3.91
Books, Periodicals	.55	.54	.65	1.33
Writing & Other Fine Paper	.30	.33	.43	1.09
Disposable Products	0	0	0	0
Beverage Containers	.27	.45	.56	1.20
Other Packaging & Containers	4.07	5.03	5.84	11.50
Consumer & Institutional Products	.09	.11	.16	.56
Furniture & Furnishings	.52	.71	.92	1.42
Apparel	1.10	1.42	1.48	2.61
Footwear	0	0	0	0
Household Durables	.12	.17	.34	1.13
Electrical & Electronic Products	.46	.49	.69	1.52
Machinery & Industrial Equipment	.51	.52	.99	2.24
Automobiles	12.79	16.56	18.51	14.56
Other Transportation	3.36	3.13	3.40	4.72
Tires & Inner Tubes	.10	.16	.16	.48
Batteries	.34	.52	.46	1.05
Buildings & Structures	1.11	1.69	2.36	4.22
Ordnance	.03	.04	.04	.08
Other Industrial Applications	0	0	0	0
Miscellaneous	.14	.18	.40	1.06
New Scrap	35.79	34.98	41.60	52.10
TOTAL NON-FOOD RECOVERY	63.63	68.89	81.15	106.78
Food Waste	0	0	0	0
TOTAL PRODUCT RECOVERY	63.63	68.89	81.15	106.78
Yard Waste	0	0	0	0
TOTAL	63.63	68.89	81.15	106.78

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation.

TABLE 17. REFERENCE SCENARIO SUMMARY OF NET SOLID WASTE PER CAPITA AND PER DOLLAR OF GNP, 1971-1990

Sector/Description	1971	1980	1990	Average Annual Percentage Growth 1971 - 1990
All Sectors:				
Net Solid Waste Per Capita (Tons)	.91	1.13	1.31	1.49
Kilos per capita per day	2.71	3.10	3.60	1.49
Net Solid Waste Per $1000 GNP (Tons)	.19	.18	.16	-0.90
Residential/Commercial Sector:				
Net Solid Waste Per Capita (Tons)	.55	.61	.67	1.04
Kilos per capita per day	1.51	1.66	1.83	1.04

Source: International Research and Technology Corporation.

As would be expected, the projected amounts of paper, glass, steel, and wood in the waste load are greater in the Constant Technology Scenario, while the amounts of aluminum and plastic are less. Food and yard waste projections are the same for all scenarios, since these components are estimated as a function of projected population and residential housing demand, respectively, both of which are the same in each scenario. The concrete waste estimates are also the same since this component emanates from buildings and structures erected prior to 1971. The effect of the Constant Technology Scenario assumptions on the total net solid waste projection is an additional 18 million tons by 1990, an increase of 5.5 percent over the Reference Scenario projection. However, the Constant Technology Scenario projects substantially higher amounts of recycled materials, especially steel, glass, and wood, resulting in a total recycled material estimate for 1990 that is 34 million tons greater than that of the Reference Scenario, reflecting a difference of 32 percent. A large part of this difference can be attributed to the continued reliance on steel in the manufacture of automobiles and other products, as assumed in the Constant Technology Scenario (combined with the relatively higher recycling rate for this material), as well as to the continued reliance on the use of glass in beverage containers, which is also assumed. The projections show substantially lower amounts of aluminum and plastics recovered or disposed of as waste, as a result. Substantial differences are also shown for wood and leather, materials that are substituted for at fairly high rates in the Reference Scenario.

TABLE 18. COMPARISON OF 1980 NET SOLID WASTE PROJECTIONS BY MATERIAL (Million Metric Tons)

Material	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Aluminum	1.94	1.64	1.86	2.05	1.87
Concrete, Masonry	64.50	64.50	51.50	64.50	64.50
Copper	1.22	1.22	1.16	1.23	1.16
Ferrous Metals	37.91	40.06	32.57	40.86	35.24
Glass	14.67	16.21	14.40	14.71	14.63
Lead	.31	.34	.18	.34	.25
Leather	.59	.65	.59	.59	.59
Paper	20.90	22.22	20.89	21.08	20.53
Plastics	5.94	5.37	5.63	5.94	5.94
Rubber	2.46	2.43	2.46	2.46	2.45
Textiles	2.20	2.24	2.17	2.20	1.97
Wood	34.79	35.85	33.88	34.79	34.79
Zinc	.81	.83	.81	.83	.72
Paperboard	18.54	19.76	18.35	18.54	18.13
TOTAL NON-FOOD	206.78	213.32	186.45	210.12	202.77
Food Waste	20.09	20.09	20.09	20.09	20.09
TOTAL PRODUCT	226.87	233.41	206.54	230.21	222.86
Yard Waste	25.12	25.12	25.12	25.12	25.12
TOTAL	251.99	258.53	231.66	255.33	247.98

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10 %.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 19. COMPARISON OF 1980 NET SOLID WASTE PROJECTIONS BY PRODUCT CATEGORY (Million Metric Tons)

Product Category	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Newspapers	6.47	6.86	6.47	6.64	6.26
Books, Periodicals	5.25	5.50	5.25	5.25	5.19
Writing/Other Fine Paper	3.52	3.67	3.52	3.52	3.47
Disposable Products	.93	1.00	.93	.93	.93
Beverage Containers	7.84	8.04	7.84	7.96	7.78
Other Packaging	38.18	43.14	38.18	38.48	37.60
Consumer/Inst. Products	7.14	7.16	6.90	7.20	7.05
Furniture & Furnishings	4.15	4.18	4.08	4.21	4.05
Apparel	.87	.87	.86	.87	.72
Footwear	.64	.67	.64	.64	.64
Household Durables	3.44	3.45	3.29	3.60	3.41
Electric/Electron. Prod.	6.10	6.10	5.53	6.11	6.05
Machinery/Indust. Equip.	8.57	8.57	8.18	9.00	8.47
Automobiles	4.00	3.98	3.83	5.05	2.15
Other Transportation	1.07	1.07	1.01	1.27	.73
Tires & Inner Tubes	1.73	1.74	1.78	1.73	1.72
Batteries	.11	.13	0	.14	.07
Buildings & Structures	97.96	97.96	83.08	98.50	97.72
Ordnance	.34	.36	.35	.36	.33
Miscellaneous	3.72	3.71	0	3.92	3.68
New Scrap	4.75	5.15	4.75	4.75	4.75
TOTAL NON-FOOD	206.78	213.31	186.47	210.13	202.77
Food Waste	20.09	20.09	20.09	20.09	20.09
TOTAL PRODUCT	226.87	233.40	206.56	230.22	222.86
Yard Waste	25.12	25.12	25.12	25.12	25.12
TOTAL	251.99	258.52	231.68	255.34	247.98

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 20. COMPARISON OF 1980 RECYCLING PROJECTIONS BY MATERIAL (Million Metric Tons)

Material	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Aluminum	1.78	1.55	1.70	1.66	1.85
Concrete, Masonry	0	0	0	0	0
Copper	1.68	1.71	1.65	1.66	1.74
Ferrous Metals	50.00	56.34	49.06	47.04	52.67
Glass	1.69	1.80	1.69	1.64	1.72
Lead	.67	.78	.22	.63	.73
Leather	0	0	0	0	0
Paper	5.70	6.08	5.70	5.53	6.07
Plastics	.37	.32	.37	.37	.37
Rubber	.20	.20	.21	.21	.22
Textiles	2.59	2.62	2.55	2.59	2.82
Wood	8.66	9.73	8.66	8.66	8.66
Zinc	.37	.39	.37	.35	.47
Paperboard	7.45	8.05	7.45	7.45	7.86
TOTAL NON-FOOD	81.16	89.57	79.63	77.79	85.18
Food Waste	0	0	0	0	0
TOTAL PRODUCT	81.16	89.57	79.63	77.79	85.18
Yard Waste	0	0	0	0	0
TOTAL	81.16	89.57	79.63	77.79	85.18

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 21. COMPARISON OF 1980 RECYCLING PROJECTIONS BY PRODUCT CATEGORY (Million Metric Tons)

Product Category	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Newspapers	2.16	2.29	2.16	2.00	2.37
Books, Periodicals	.65	.68	.65	.65	.71
Writing/Other Fine Paper	.43	.45	.43	.43	.48
Disposable Products	0	0	0	0	0
Beverage Containers	.56	.57	.56	.44	.61
Other Packaging	5.84	6.67	5.84	5.55	6.43
Consumer/Inst. Products	.16	.16	.16	.10	.25
Furniture & Furnishings	.92	.92	.89	.85	1.01
Apparel	1.48	1.48	1.47	1.48	1.63
Footwear	0	0	0	0	0
Household Durables	.34	.34	.33	.19	.37
Electric/Electron. Prod.	.69	.69	.61	.68	.74
Machinery/Indust. Equip.	.99	.99	.95	.56	1.09
Automobiles	18.51	18.55	18.29	17.46	20.36
Other Transportation	3.40	3.40	3.31	3.20	3.74
Tires & Inner Tubes	.16	.16	.17	.17	.18
Batteries	.46	.53	0	.43	.50
Buildings & Structures	2.36	2.36	2.15	1.82	2.60
Ordnance	.04	.05	.05	.03	.05
Other Industrial Appl.	0	0	0	0	0
Miscellaneous	.40	.40	0	.20	.44
New Scrap	41.60	48.86	41.60	41.60	41.60
TOTAL NON-FOOD	81.15	89.55	79.62	77.84	85.15
Food Waste	0	0	0	0	0
TOTAL PRODUCT	81.15	89.55	79.62	77.84	85.15
Yard Waste	0	0	0	0	0
TOTAL	81.15	89.55	79.52	77.84	85.15

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 22. COMPARISON OF 1990 NET SOLID WASTE PROJECTIONS BY MATERIAL (Million Metric Tons)

Material	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Aluminum	2.39	2.03	2.30	2.96	2.24
Concrete, Masonry	101.15	101.15	80.77	101.15	101.15
Copper	1.38	1.39	1.39	1.42	1.31
Ferrous Metals	36.87	41.74	31.50	47.64	34.61
Glass	18.54	23.53	18.18	18.97	18.46
Lead	.33	.39	.22	.35	.21
Leather	.84	1.02	.84	.84	.84
Paper	28.50	32.54	28.48	30.43	27.79
Plastics	10.27	8.01	9.80	10.27	10.27
Rubber	4.29	3.78	4.17	4.44	4.24
Textiles	3.48	3.68	3.39	3.48	3.11
Wood	37.32	40.53	36.35	37.32	37.32
Zinc	.87	.92	.87	.95	.74
Paperboard	24.59	27.92	24.32	26.06	23.86
TOTAL NON-FOOD	270.82	288.63	242.58	286.48	266.15
Food Waste	22.10	22.10	22.10	22.10	22.10
TOTAL PRODUCT	292.92	310.73	264.68	308.58	288.25
Yard Waste	29.84	29.84	29.84	29.84	29.84
TOTAL	322.76	340.57	294.52	338.42	318.09

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 23. COMPARISON OF 1990 NET SOLID WASTE PROJECTIONS BY PRODUCT CATEGORY (Million Metric Tons)

Product Category	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Newspaper	9.11	10.35	9.11	10.02	8.72
Books, Periodicals	6.96	7.82	6.96	7.38	6.83
Writing/Other Fine Paper	5.71	6.38	5.71	6.05	5.60
Disposable Products	1.32	1.51	1.32	1.32	1.32
Beverage Containers	7.03	9.62	7.03	7.76	6.91
Other Packagin	45.11	54.85	45.11	49.19	43.96
Consumer/Inst. Products	10.52	11.02	10.19	10.94	10.36
Furniture & Furnishings	4.78	5.43	4.58	5.05	4.63
Apparel	1.51	1.55	1.49	1.51	1.25
Footwear	.98	1.07	.99	.98	.98
Household Durables	4.75	5.01	4.43	5.61	4.63
Electric/Electron. Prod.	6.74	6.91	6.69	7.31	6.61
Machinery/Indust. Equip.	9.55	9.68	9.56	11.12	9.33
Automobiles	4.13	3.93	3.86	5.81	3.34
Other Transportation	1.10	1.10	1.07	1.68	.84
Tires & Inner Tubes	3.10	2.77	3.01	3.25	3.05
Batteries	.12	.13	0	.29	.01
Building & Structures	137.58	137.58	115.07	139.61	137.16
Ordnance	.30	.36	.30	.36	.29
Other Industrial Appl.	0	0	0	0	0
Miscellaneous	4.33	4.32	0	5.13	4.23
New Scrap	6.08	7.22	6.08	6.08	6.08
TOTAL NON-FOOD	270.81	288.61	242.56	286.45	266.13
Food Waste	22.10	22.10	22.10	22.10	22.10
TOTAL PRODUCT	292.91	310.71	264.66	308.55	288.23
Yard Waste	29.84	29.84	29.84	29.84	29.84
TOTAL	322.75	340.55	294.50	338.39	318.07

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 24. COMPARISON OF 1990 RECYCLING PROJECTIONS BY MATERIAL (Million Metric Tons)

Material	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Aluminum	3.24	2.65	3.17	2.67	3.39
Concrete, Masonry	0	0	0	0	0
Copper	2.18	2.38	2.19	2.14	2.26
Ferrous Metals	59.69	86.80	58.31	48.92	61.95
Glass	2.59	3.16	2.59	2.17	2.67
Lead	1.39	1.65	.34	1.18	1.51
Leather	0	0	0	0	0
Paper	9.86	11.27	9.86	7.94	10.57
Plastics	.65	.47	.65	.65	.65
Rubber	.54	.47	.53	.39	.59
Textiles	4.15	4.32	4.05	4.15	4.52
Wood	10.04	13.25	10.04	10.04	10.04
Zinc	.52	.53	.53	.44	.65
Paperboard	11.89	13.77	11.89	10.42	12.62
TOTAL NON-FOOD	106.75	140.72	104.15	91.11	111.42
Food Waste	0	0	0	0	0
TOTAL PRODUCT	106.75	140.72	104.15	91.11	111.42
Yard Waste	0	0	0	0	0
TOTAL	106.75	140.72	104.15	91.11	111.42

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

TABLE 25. COMPARISON OF 1990 RECYCLING PROJECTIONS BY PRODUCT CATEGORY (Million Metric Tons)

Product Category	Reference[1]	Constant Technology[2]	Increased Product Lifetime[3]	Constant Recycling[4]	Increased Recycling[5]
Newspapers	3.91	4.44	3.91	2.99	4.30
Books, Periodicals	1.33	1.49	1.33	.91	1.46
Writing/Other Fine Paper	1.09	1.22	1.09	.75	1.20
Disposable Products	0	0	0	0	0
Beverage Containers	1.20	1.69	1.20	.47	1.32
Other Packaging	11.50	15.36	11.50	7.42	12.65
Consumer/Inst. Products	.56	.64	.54	.14	.71
Furniture & Furnishings	1.42	1.60	1.35	1.14	1.57
Apparel	2.61	2.67	2.57	2.61	2.87
Footwear	0	0	0	0	0
Household Durables	1.13	1.27	1.06	.27	1.25
Electric/Electron. Prod.	1.52	1.54	1.50	.94	1.64
Machinery/Indust. Equip.	2.24	2.27	2.24	.67	2.46
Automobiles	14.56	24.47	14.70	12.88	15.35
Other Transportation	4.72	4.77	4.69	4.14	4.98
Tires & Inner Tubes	.48	.41	.46	.33	.53
Batteries	1.05	1.20	0	.87	1.15
Buildings & Structures	4.22	4.22	3.82	2.20	4.65
Ordnance	.08	.11	.08	.02	.09
Other Industrial Appl.	0	0	0	0	0
Miscellaneous	1.06	1.06	0	.27	1.17
New Scrap	52.10	70.27	52.10	52.10	52.10
TOTAL NON-FOOD	106.75	140.70	104.14	91.12	111.45
Food Waste	0	0	0	0	0
TOTAL PRODUCT	106.75	140.70	104.14	91.12	111.45
Yard Waste	0	0	0	0	0
TOTAL	106.75	140.70	104.14	91.12	111.45

Note: Totals for material and product categories may not be the same due to rounding.

Source: International Research and Technology Corporation, January, 1979.

[1] Scenario assumes moderate change in technology, materials substitution and recycling rates during the forecast period.

[2] Scenario assumes no change in technology or mix of materials use in forecast period.

[3] Scenario assumes average lifetime of products to increase 10%.

[4] Scenario assumes no change in post-consumer recycling rates during forecast period.

[5] Scenario assumes 10% increase in post-consumer recycling rates over reference case assumptions.

The Constant Technology Scenario shows that in the absence of materials substitution and technology change, the quantity of solid waste that will have to be managed in future years may be slightly greater if past and current trends in substitution were to cease. Alternatively, the scenario suggests that substantially higher quantities of the materials that are relatively easy to recycle can be recovered, since the projected net waste load of the Constant Technology Scenario in 1990 is only 5.5 percent higher than that of the Reference Scenario, while the estimate of total recycled material is 31.8 percent higher.

THE EFFECTS OF PRODUCT LIFE

The lowest net solid waste projection is found in the Increased Product Lifetime Scenario. For this projection, the assumed average product lifetime was increased 10 percent over Reference Scenario values for all products with average lifetimes over 1 year. All other assumptions of the Reference Scenario were maintained, including the new scrap factors and recycling rates for new and old scrap.

The impacts of the assumptions are greatest on the projections for steel and concrete, materials that are typically used in products with relatively long average lifetimes - household durables, automobiles, and particularly, buildings and structures. The differences in the projections for these two materials alone account for over 90 percent of the total difference between scenarios. For all other materials, the differences are less than 5 percent, since they are typically incorporated in products with relatively short average lifetimes. The projected total net solid waste load for 1990 in the Increased Product Lifetime Scenario is over 28 million metric tons lower (8.7 percent) than that of the Reference Scenario, while the quantity of materials recycled is less than 3 million metric tons lower (2.4 percent).

THE IMPACTS OF RECYCLING

For two of the alternate scenarios, variations in the recycling assumptions of the Reference Scenario were examined. Both of these alternate scenarios employ the technology change, materials substitution, new scrap, and product life assumptions of the Reference Scenario. One scenario, called Constant Recycling, assumes no change in the recycling rates for old scrap from 1976 on, and the other, called Increased Recycling, reflects an assumed 10 percent increase in the Reference Scenario recycling rates, for all materials in all products, for all forecast years. These recycling assumptions were applied at the point of disposal; the new scrap and other diversion rates assumed in the Reference Scenario were not changed. The old scrap recycling rates assumed for 1990 in each scenario are shown in Table 26.

The results suggest that the greatest post-consumer resource recovery potential lies with metals. The amount of unrecycled metal in the 1990

TABLE 26. RECYCLING ASSUMPTIONS OF EACH SCENARIO FOR 1990 (OLD SCRAP--POST-CONSUMER)*

PRODUCT CATEGORY	PAPER			PAPERBOARD			GLASS			ALUMINUM			ZINC		
	R	CR	IR	R	CR	IR	R	CR	IR	R	CR	IR	R	CR	IR
Newspapers	.30	.23	.33												
Books & Periodicals	.16	.11	.18	.16	.11	.18									
Writing Paper	.16	.11	.18												
Disposables															
Beverage Containers							.06	.03	.07	.30	.15	.33			
Other Packaging	.15	.10	.17	.25	.20	.28	.06	.03	.07	.10	0	.11			
Consumer & Institutional Products				.15	.10	.17				.20	.09	.22	.06	.06	.07
Furniture										.20	.09	.22			
Apparel															
Household Durables										.25	.15	.28	.10	.10	.11
Electrical/Electronics										.95	.93	1.00	.29	.23	.31
Machinery & Industrial Equipment										.30	.25	.33	.10	.10	.11
Automobiles										.60	.30	.66	.20	.20	.22
Other Transportation										.60	.30	.66	.20	.20	.22
Tires															
Batteries															
Construction										.20	.13	.22	.52	.30	.57
Ordnance															
Other Industrial										.20	.09	.22			
Miscellaneous															

(continued)

TABLE 26 (continued)

PRODUCT CATEGORY	COPPER			LEAD			FERROUS METALS			TEXTILES			RUBBER		
	R	CR	IR	R	CR	IR	R	CR	IR	R	CR	IR	R	CR	IR
Newspapers															
Books & Periodicals															
Writing Paper															
Disposables															
Beverage Containers							.50	.15	.55						
Other Packaging				.80	.65	.88	.50	.15	.55						
Consumer & Institutional Products	.19	.18	.21	.50	.20	.55	.20	.01	.22						
Furniture							.20	.01	.22	.66	.66	.73			
Apparel										.66	.66	.73			
Household Durables	.38	.36	.42				.25	.05	.28						
Electrical/Electronics	.38	.36	.42	.90	.40	.99	.10	.00	.11						
Machinery & Industrial Equipment	.40	.37	.44				.20	.05	.22						
Automobiles	.33	.31	.36				.95	.85	1.00						
Other Transportation	.33	.31	.36				.95	.85	1.00						
Tires													.15	.10	.17
Batteries				.90	.75	.99									
Construction	.30	.29	.33	.30	.30	.33	.30	.15	.33						
Ordnance	.19	.18	.21	.50	.20	.55	.20	.05	.22						
Other Industrial							.20	.05	.22						
Miscellaneous							.20	.05	.22						

*Figures indicate the fraction of total old (post-consumer) scrap assumed to be available for recycling for reuse.

Note: R denotes Reference and other scenarios.
CR denotes Constant Recycling
IR denotes Increased Recycling
For materials and products not shown, the recycling rate is assumed to be zero (plastics, wood, leather and concrete recycling rates are zero).

Source: Compiled by International Research and Technology Corporation. For more information on sources of information, see Appendix.

waste load is more than 11 million metric tons higher in the Constant Recycling Scenario than in the Reference Scenario, reflecting a difference of 28 percent. Household durables and transportation equipment account for the bulk of the difference. The fraction of aluminum recovered from junked automobiles is assumed to double in the Reference Scenario, from 30 percent in 1971 to 60 percent in 1990, in contrast to the Constant Recycling Scenario, in which only 30 percent of the aluminum from automobiles scrapped in 1990 is recovered. Similarly, 85 percent of the steel in automobiles scrapped in 1971 was recovered, and this fraction increases to 95 percent in the Reference Scenario. In the Constant Recycling Scenario, the fraction remains at 85 percent throughout the forecast. The impact on the total net waste load is a projection that is 15.7 million metric tons greater than that of the Reference Scenario; a difference of 4.9 percent.

In the Increased Recycling Scenario, the change is less dramatic, but still significant. The difference between the two scenarios regarding the net waste load projection for 1990 is only 1.4 percent, but the amounts of steel, aluminum, other metals and textiles are 6 to 12 percent lower than the amounts in the Reference Scenario.

SECTION 3

COMPARISON OF ESTIMATES AND FORECASTS OF THE QUANTITY AND COMPOSITION OF SOLID WASTE

Previous studies reporting estimates of solid waste and its composition vary in scope and, to some extent, in definitions of product categories analyzed. In the forecast years, estimates vary primarily due to differences in basic assumptions. In this section, comparisons are made between estimates provided by this study with estimates used by EPA, and estimates from other studies.

Sources of solid waste are usually categorized as either residential, commercial/institutional, or municipal. The latter is roughly a consolidation of the residential and commercial categories. In the IR&T study, the residential and commercial contributions to the total solid waste load are estimated on the basis of aggregating specific product categories assumed to emanate from these sectors. Comparisons of post-consumer residential and commercial solid waste estimates by IR&T and EPA (7,36) are provided in Tables 27 and 28. Estimates of total waste differ by only 0.7 percent in 1971, and by 7.4 percent in 1975. Although the estimates of total waste from these sectors are quite similar, there are some fairly large differences between estimates for specific materials and product categories. In order to clarify the reasons for these discrepancies, EPA's descriptions of solid waste categories and methodologies are briefly discussed.

The EPA estimates exclude agricultural, mining, and industrial processing waste; construction and demolition residuals; street sweepings (except packaging material); heavy or bulky tree and landscape waste (except normal yard waste); sewage sludge; and residuals from automobiles and trucks (except tires). These items have similarly been excluded from the IR&T estimates of residential and commercial waste. IR&T's estimates of transportation equipment, industrial and demolition wastes are included in Table 29, only to emphasize the scope of the present study on solid waste.

It would appear from the table that the discrepancies between estimates for individual material and product categories are not due to differences in materials or product categories. Differences in the description of some product end-use markets and methodologies employed may explain some of the variations, although the approach used by both IR&T and EPA was to analyze the flow of materials from production through consumption to disposal. Both studies use production data for each material and both include net exports to obtain estimates of apparent domestic consumption. Nevertheless, discrep-

TABLE 27. COMPARISON OF POST-CONSUMER NET RESIDENTIAL AND COMMERCIAL SOLID WASTE BY MATERIAL (Million Metric Tons)

	1971			1975		
Material	IR&T	EPA	Percent Diff.*	IR&T	EPA	Percent Diff.*
Paper	33.5	33.5	- 5.6	34.0	33.8	.6
Glass	10.3	10.9	- 5.5	12.9	12.1	6.6
Metal	18.4	10.7	72.0	20.0	11.1	80.2
Ferrous	(16.9)	(9.6)	(76.0)	(18.2)	(9.8)	(85.7)
Aluminum	(.8)	(.7)	(14.3)	(1.0)	(.8)	(25.0)
Other	(.7)	(.4)	(75.0)	(.8)	(.4)	(100.0)
Plastics	3.0	3.8	-21.1	4.0	4.0	0.0
Rubber & Leather	1.9	3.0	-36.7	2.3	3.0	-23.3
Textiles	1.2	1.6	-25.0	1.7	1.9	-10.5
Wood	6.8	4.2	61.9	8.4	4.5	86.7
TOTAL NON-FOOD PRODUCT WASTE	75.1	69.9	7.4	83.3	70.5	18.2
Food Waste	18.7	20.0	- 6.5	19.3	20.7	- 6.8
TOTAL PRODUCT WASTE	93.8	89.9	4.3	102.6	91.2	12.5
Yard Waste	20.4	21.9	- 6.9	22.5	23.6	- 4.7
Misc. Inorganics	--	1.6	--	--	1.7	--
TOTAL	114.2	113.4	.7	125.1	116.5	7.4

Note: Totals may not add due to rounding. Parentheses indicate estimates for subcomponents of the metals category.

* Percent difference is calculated using the formula: [(IR&T/EPA)-1] x 100

Source: International Research and Technology Corporation.
Frank A. Smith, "Comparative Estimates of Post-Consumer Solid Waste," Resource Recovery Division, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, May 1975; and, *Resource Recovery and Waste Reduction.* Fourth Report to Congress, SW-600, Office of Solid Waste, U.S. Environmental Protection Agency, 1977.

ancies between material data used in each analysis may be in part due to differences in conversion factors used to change reported units of bulk consumption into tonnage data (e.g., lumber feet into tons of wood, or number of glass containers into tons of glass, etc.). In addition, variations in other adjustments to the data, such as diversions and time lags, may help explain differences in the material estimates of solid waste. It should be noted that the estimates of total residential and commercial waste are virtually identical in 1971, and fairly close in 1975.

TABLE 28. COMPARISON OF POST-CONSUMER NET RESIDENTIAL AND COMMERCIAL SOLID WASTE BY PRODUCT CATEGORY (Million Metric Tons)

	1971			1975		
Product	IR&T	EPA	Percent Diff.*	IR&T	EPA	Percent Diff.*
Newspapers, Books, Magazines	13.5	9.4	43.6	15.0	8.9	68.5
Containers/Packaging	41.9	37.9	10.6	45.0	37.9	18.7
Major Household Appl.	2.3	1.9	21.1	2.9	2.1	38.1
Furniture/Furnishings	3.3	2.9	13.8	3.7	3.1	19.4
Clothing & Footwear	1.2	1.1	9.1	1.4	1.2	16.7
Other Products	12.9	16.7	-22.8	15.4	17.2	-10.5
TOTAL NON-FOOD PRODUCT WASTE	75.1	69.9	7.4	83.4	70.5	18.2
Fook Waste	18.7	20.0	- 6.5	19.3	20.7	- 6.8
TOTAL PRODUCT WASTE	93.8	89.9	4.3	102.7	91.2	12.5
Yard/Misc. Organics	20.4	23.5	-13.2	22.5	25.4	-11.4
TOTAL	114.2	113.4	.7	125.2	116.5	7.5

Note: Totals may not add due to rounding.

* Percent difference is calculated using the formula: [(IR&T/EPA) - 1] x 100

Source: International Research and Technology Corporation. Frank A. Smith, "Comparative Estimates of Post-Consumer Solid Waste," Resource Recovery Division, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, May 1975; and, *Resource Recovery and Waste Reduction.* Fourth Report to Congress, SW-600, Office of Solid Waste, U.S. Environmental Protection Agency, 1977.

implying that the major differences for specific materials are due to the manner in which each study chose to allocate materials to product categories.

The largest percentage difference between estimates for 1971 lies with metals. The EPA estimates of ferrous metals in net solid waste are based on a study by W.J. Regan, et al., (37), while IR&T used a time series on steel shipments by detailed product category from the American Iron and Steel Institute (38,39). Regan, who uses estimates provided by Battelle Memorial Institute (40), reports that the determination of obsolescent or post-consumer scrap is a "complex, imprecise calculation." Regan also indicates that the Battelle steel estimates are provided only as a "rough approximation of magnitude." Consequently, it would appear that the American Iron and Steel Insti-

TABLE 29. ESTIMATES OF TRANSPORTATION, INDUSTRIAL, DEMOLITION AND CONSTRUCTION WASTES FOR THE YEAR 1971 (Million Metric Tons)

Solid Waste Source Sector and Product Category		
Transportation	4.4	
Automobiles		3.3
Batteries		.1
Other Transportation		1.0
Industrial	12.7	
Machinery & Equipment		8.0
Ordnance		.8
New Scrap		3.9
Demolition	74.1	
Construction	1.4	

Source: International Research and Technology Corporation.

tute time series data used by IR&T in conjunction with materials-flow analysis and input-output techniques, may provide more reliable estimates of the amount of steel in the solid waste load.

IR&T data for aluminum, copper, lead, and zinc are based on time series published in government sources as outlined in the appendix. EPA suggests that their estimation procedure was adjusted for nonferrous metals and plastics due to a lack of detailed knowledge for these materials. IR&T's estimate for the "other" metal category is much larger than that of EPA's, due to the inclusion by IR&T of specific zinc, lead and copper estimates; the EPA emphasis is on copper and lead in the waste stream.

Estimates of the amount of plastic in the 1971 residential and commercial waste are much closer, and for 1975, they are identical. The different estimates for 1971 may be explained by differences in data sources used. EPA uses estimates for major resins only; their estimates are derived from two data sources that provide statistics for the "big-five" polymers: low density polyethylene, high density polyethylene, polystyrene, polyvinyl chloride, and polypropylene. To estimate total use of plastics, EPA assumes that these five materials comprise 88 percent of all plastics used in packaging, and 67 percent (a 1970 estimate) of all plastics used in major appliances, furniture, apparel, footwear, and other products. However, IR&T uses time series data from *Modern Plastics* (41) by resin and product category, so that adjustments to obtain control totals were not necessary.

Large discrepancies also exist between the EPA and IR&T estimates of wood in residential and commercial waste, although both studies employed time series data from the Forest Service (42). EPA, however, states that wood packing and shipping materials discarded by the shipping end-use category are used solely in industrial applications, while IR&T assumes that this category should be included in the commercial waste stream. Consequently, the IR&T wood waste estimate is substantially higher than EPA's.

Definitional differences are the primary cause for discrepancies between estimates by product category. IR&T includes writing and other fine paper with newspapers, books and magazines. As stated previously, IR&T includes wooden packaging and containers with commercial wastes while EPA delegates this category to industrial waste. Also, EPA assumes that most of the other nonferrous metals category is comprised of copper and lead. EPA did not trace materials-flows, but instead obtained data on copper waste from Battelle (40) and estimates of tin and lead consumed in tin can manufacture from another EPA study (45). An arbitrary figure of 0.1 million tons was used to estimate all other nonferrous metals, which seems to be the major explanation for the difference between IR&T and EPA. IR&T's estimates for copper, lead, and zinc are based on time series data from the Bureau of Mines (44). Zinc used in household durables, commercial and institutional products, and electrical/electronic products amounted to 302 thousand metric tons - over a quarter of total zinc use in 1971.

IR&T and EPA projections of post-consumer solid waste are compared in Table 30. The EPA projections are based on product end-use analyses for all major categories by Midwest Research Institute (26). The table compares estimates of gross discards (total waste generation before recycling), material recovery (diversions from post-consumer discards), and net waste disposal (final residual wastes remaining after material recovery). EPA's projections are referred to as "base line" by EPA and by Midwest Research Institute, since the projections assume no new intervention by the federal government with regard to resource recovery or waste reduction incentive programs; no new regulations on non-hazardous waste disposal; and no other new programs in the solid waste management field.

As can be seen in Table 30, estimates by IR&T and EPA of total net solid waste disposal in 1971 are identical. Slight absolute variations are found between estimates of gross discards and resource recovery. Projections of gross discards are comparable, differing by just 6.3 percent in 1990. The large differences between projected resource recovery estimates and projections of net waste disposal are due to different recycling rates assumed.

The EPA projections suggest rather rapid increases in the fraction of gross discards recycled, from about 6 percent in 1971 to about 26 percent in 1990. Such a dramatic increase seems to contradict the fundamental base line assumption of no new initiatives. EPA states that the projections are indeed hypothetical, yet the large increases in resource recovery imply the existence of large-scale waste processing installations. Without incentive programs or substantial increases in the demand for secondary materials, the EPA projections of resource recovery appear unrealistic. The IR&T projections, on the other hand, seem more reasonable, as the fraction of gross discards recovered increases from 8.1 percent in 1971 to 14.6 percent in 1990.

TABLE 30. COMPARISON OF POST-CONSUMER ESTIMATES AND PROJECTIONS OF PER CAPITA WASTE GENERATION
(Million Metric Tons)

	1971			1980			1990			Average Annual Percentage Growth 1971 - 1990	
Category/Description	IRT	EPA	% Diff.	IRT	EPA	% Diff.	IRT	EPA	% Diff.	IRT	EPA
Total Gross Discards											
Million Tons/Year	124	121	2.5	149	159	-6.3	192	205	-6.3	2.33	2.81
Kilos/Person/Day*	1.64	1.60	2.5	1.83	1.96	-6.3	2.15	2.29	-6.3	1.44	1.91
Less: Resource Recovery											
Million Tons/Year	10	7	42.9	14	17	-17.7	28	53	-47.2	5.57	11.24
Kilos/Person/Day*	.13	.09	42.9	.17	.21	-17.7	.31	.59	-47.2	4.68	10.40
Equals: Net Waste Disposal											
Million Tons/Year	114	114	0.0	135	142	-4.9	164	152	7.9	1.93	1.53
Kilos/Person/Day*	1.51	1.51	0.0	1.66	1.75	-4.9	1.83	1.70	7.9	1.02	.63

* Per capita solid waste figures were based on U.S. Census population estimates assuming a 365-day year. The population figures used were: 1971: 207.05 million; 1980: 222.80 million; 1990: 245.08 million.

Source: International Research and Technology Corporation, January 1979. Frank A. Smith, "Quantity and Composition of Post-Consumer Solid Waste: Material Flow Estimates for 1973 and Baseline Future Projections," *Waste Age*, April 1976.

TABLE 31. COMPARISON OF POST-CONSUMER ESTIMATES AND PROJECTIONS (Million Metric Tons)

	1971			1975			1980			1990			Average Annual Percentage Growth 1971 - 1990	
Material	IR&T	MRI	% Diff.*	IR&T	MRI	% Diff.*	IR&T	MRI	% Diff.*	IR&T	MRI	% Diff.*	IR&T	MRI
Paper	33.5	35.5	- 5.6	36.0	38.3	-11.2	37.4	46.0	-18.7	50.3	61.1	-17.7	2.16	2.90
Glass	10.3	11.0	- 6.4	12.9	13.2	- 2.3	13.6	14.9	- 8.7	16.9	15.4	9.7	2.64	1.79
Metals	18.4	10.8	70.4	20.0	12.1	65.3	21.4	13.7	56.2	20.7	17.6	17.6	.62	2.60
Ferrous	(16.9)	(9.7)	74.2	(18.2)	(10.6)	71.7	(19.3)	(11.9)	62.12	(18.3)	(14.9)	22.8	.42	2.28
Aluminum	(.8)	(.7)	14.3	(1.0)	(1.1)	- 9.1	(1.2)	(1.4)	-14.3	(1.4)	(2.1)	-33.3	2.99	5.95
Other Non-Ferrous	(.7)	(.4)	75.0	(.8)	(.4)	100.0	(.9)	(.5)	80.0	(1.1)	(.6)	83.3	2.41	2.16
Plastics	3.0	3.8	-21.1	4.0	5.2	-23.2	5.2	7.6	-31.6	8.4	12.0	-30.0	5.37	6.24
Rubber & Leather	1.9	3.0	-36.7	2.3	3.4	-32.4	2.5	3.9	-35.9	4.3	5.3	-18.9	4.39	3.06
Textiles	1.2	1.6	-25.0	1.7	1.9	-10.5	2.0	2.2	- 9.1	3.1	3.2	- 3.1	5.12	3.72
Wood	6.8	4.2	61.9	8.4	4.6	82.6	7.9	5.2	51.9	8.2	6.7	22.4	.99	2.49
Food Wastes	18.7	20.0	- 6.5	19.3	20.9	- 7.7	20.1	22.3	- 9.9	22.1	25.2	-12.3	.88	1.22
Yard Wastes	20.4	21.9	- 6.9	22.5	23.9	- 5.9	25.1	26.6	- 5.6	29.8	33.1	-10.0	2.01	2.20
Miscellaneous Organics	--	1.7	--	--	1.9	--	--	2.3	--	--	3.0	--	--	3.03
TOTAL	114.2	113.6	.5	125.1	125.4	- .2	135.2	144.7	- 6.6	169.9	182.5	-10.2	1.92	2.53
Kilos/Person/Day**	1.51	1.50	.5	1.60	1.61	- .2	1.66	1.78	- 6.6	1.83	2.04	-10.2	1.02	1.63

Note: Totals may not add due to rounding.

* Percent difference is calculated using the formula: [(IR&T/EPA) - 1] x 100

** Per capita solid waste figures were based on U.S. Census population estimates assuming a 365 day year. The population figures used were 1971: 207.05 million; 1975: 213.60 million; 1980: 222.80 million; 1990: 245.05 million.

Source: International Research and Technology Corporation.
Midwest Research Institute, *Base Line Forecasts of Resource Recovery, 1972 to 1990*, Final Report, U.S. Environmental Protection Agency, 1975.

MRI's projections by material category are compared with IR&T's projections in Table 31. The starting point for the MRI projections is the set of 1971 values developed by EPA. The MRI and IR&T total solid waste estimates in 1971 and 1975 are nearly identical, but show variations in 1980 and 1990; however, large discrepancies are found between estimates for specific materials. Although the MRI approach is based on a materials-flow analysis (i.e., input approach), in which the flow of materials through production and consumption stages are traced, for a number of materials (notably glass, ferrous metals and plastics) estimates were arbitrarily adjusted based on judgement. The major discrepancies are found in comparing estimates for metals and wood. A detailed analysis of aluminum waste was conducted by MRI, but estimates for other nonferrous metals are based on EPA data for 1971 that were discussed previously. MRI increased EPA estimates for nonferrous metals in 1980, 1985, and 1990 by 0.1 million tons arbitrarily. In contrast, IR&T performed materials-flow analyses for aluminum, copper, zinc, and lead, using historical data published by various government sources. To project wood wastes, MRI extrapolated EPA's 1971 estimate using an assumed average annual percentage growth rate of 2.5. Using IR&T's materials-flow approach coupled with input-output techniques, wood wastes are projected to increase less than 1.0 percent per year.

Similarly, the MRI textile waste projection is based on EPA's estimate for 1971 and an assumed growth rate of 3.7 percent per year. A much higher growth in textile wastes is projected using the IR&T materials-flow methodology. MRI projections of rubber and leather waste are presented together, although different methodologies were used for the two materials. In the analysis of the rubber end-use market, MRI assumed that 75 percent of all rubber waste is comprised of discarded tires and inner tubes. The balance is comprised of rubber from other uses, of which half is assumed to be discarded in the residential and commercial waste stream. MRI projects leather waste based on EPA's data for 1971, and an assumed average annual growth rate of 3.0 percent. IR&T's analysis yields a projected growth rate of 4.4 percent per year for rubber and leather, based on time series of production data for both materials.

In the MRI study, six materials were analyzed in detail: ferrous metals, aluminum, glass, plastics, rubber and paper. The analysis included demand forecasts for each industry producing these materials, estimates of the generation of waste by source, and estimates of the quantities of recoverable materials. With the exception of ferrous metals, differences in the forecasts for the six materials are due largely to different recycling assumptions employed or to differences in the delineation of source categories. For the other materials, the IR&T projections are not based on growth rates assumed outright, but on materials-flow analysis and on input-output techniques that take materials substitution and technology change into account. The MRI baseline forecasts are in the process of being updated, but this work will not be available until later this year. A comparison at that time may clarify the reasons for discrepancies discussed in this section.

A comparison of demolition waste estimates was also made. The Massachusetts Institute of Technology (MIT) conducted a study (45) of demolition wastes, based on a survey of Boston, Atlanta, and Los Angeles debris. An estimate for the nation was derived on the basis of 0.327 metric tons per person, an average for the three cities. IR&T's analysis of demolition wastes, based on estimates of the total amount of materials used in construction over the past fifty years, resulted in an estimate of 0.357 tons per capita in 1971, a difference of 9.2 percent. It should be noted that IR&T does employ the MIT time series as the source for the quantity of concrete that goes to the buildings and structures end-use market annually. The difference in demolition waste estimates is due to different study approaches as well as different waste sources of data for the other materials flowing to the construction end-use (e.g., ferrous metals, plastics, glass, lead, copper, aluminum, and wood). In addition, the MIT study indicates that brick and clay products constitute a fairly large proportion of demolition wastes; the inclusion of these materials in the IR&T analysis could significantly improve estimates of total demolition debris in the solid waste stream.

SECTION 4

METHODOLOGY

The methodology used to forecast the quantity and composition of solid waste combines estimation procedures using production data (i.e., materials-flow analysis) with input-output forecasting techniques. The methodology requires historical data on materials use by product manufacturers, and a linkage of this data to the economic forecasting model. As discussed briefly in Section 1, historical data on physical flows are maintained in materials/product matrices for the years 1960 to 1971. The 1971 physical data is linked to specific 1971 dollar flows in the economic model in order to estimate future physical flows on the basis of projected dollar flows. To estimate the makeup of future solid waste flows, the projected gross physical flows are adjusted to account for new scrap, imports and exports, time lags from production through consumption to disposal, and recycling of old (post-consumer) scrap.

DATA DEVELOPMENT

As described briefly in Section 1, the estimation of the quantity and composition of solid waste involves the use of production data and materials-flow analysis with input-output forecasting techniques. Production data by material and product category end-use were obtained through a literature search. The historical material data files for the years 1960-1971 for each material and the material flow diagrams for each material for the year 1971 are presented in the appendix.

The physical flows of materials, measured in tons, were obtained from data published by government agencies and trade associations. Consistency with data published by the Census (46) was established wherever possible. In the historical time series data, many of the product end-use categories were in general terms, such as "containers and packaging" or "transportation." An effort was made to disaggregate these large categories into their components, in order to forecast the composition of the solid waste stream in greater detail. For example, containers and packaging tonnage data were divided into beverage containers and other packaging and containers for the appropriate material history file, and transportation data for a particular material were divided into portions used in automobiles and other transportation. The production data for larger categories were adjusted and allocated to more specific end-uses using data from the input-output table of the economic model. For some of the material history files, it was not necessary to disaggregate the general categories to the specific end-uses, due to the fact that the detailed categories were specified (e.g., aluminum end-use categories) or that very detailed categories were compiled to meet the specific end-uses (e.g., plastics and textiles end-use categories). In addition to the present data on residential and commercial sources of solid waste, production data were also found for the buildings and structures sector and transportation equipment. This data made it possible to forecast the quantity of solid waste from transportation equipment, and from construction and demolition.

It should be noted that the number of material categories examined in this study is larger, and therefore more comprehensive, than that of previous studies. For example, specific data on nonferrous metals were obtained from government sources, while, with the exception of aluminum, the quantity of lead, zinc, and copper entering the solid waste stream has been grouped under the heading "nonferrous" in other studies. The product end-use category allocations for each material are valuable in predicting trends in recycling, materials substitution, and future demand-supply relationships in secondary materials markets. The addition of concrete to the list of materials provided the data base necessary for forecasting the bulk of demolition and construction wastes.

The following is a description of the sources of history production data by material. Time series for each material from 1960 to 1971, further information on data sources, product categories, major adjustments to the data, and sources for recycling assumptions are provided in the appendix.

Aluminum

The time series in the two Bureau of Mines publications, *Mineral Facts and Problems* (44) and Mineral Commodity Profiles *Aluminum 1977* (47) were selected to update and expand the aluminum data. The source of most of the figures on the end-use demand patterns included in these government publications is the Aluminum Associations's *Statistical Review* (48). The trade association's figures are based on shipments of finished products and semifabricated products as reported in industry questionnaires. The Bureau of Mines publications use the distribution of aluminum among product categories to allocate total aluminum figures to final end-use products.

Concrete

Consumption of concrete was assumed to be entirely for buildings and structures. The data were taken from the MIT study, *The Investigation of the Potential for Resource Recovery from Demolition Wastes* (45) published in 1976.

Copper

Data from the Bureau of Mines *Mineral Facts and Problems* (44) and Mineral Commodity Profiles in *Copper 1977* (49) were used in the model. The source of the end-use data in the two Bureau of Mines publications is Copper Development Association (50) data as well as the *Mineral Yearbook* (51) data on total annual demand for copper, which served as a control total. The Copper Development Association's source of data is industry reports on brass mill products, *Current Industrial Reports* (52,53) on insulated wire and cable, and estimates of castings and powder by the trade association's research department. The end-use data on copper were derived from company reports of shipments of sheet, strip, and plumbing, etc., to the various end-use markets.

Ferrous Metals

The methodology to derive product category estimates for iron and steel included data not previously available, as well as end-uses not previously specified in the economic model. The product category estimates are now available from the Bureau of Mines *Mineral Facts and Problems* (44). The government compiles data on steel mill shipments from the American Iron and Steel Institute's *Annual Statistical Report* (38,39) and data on foundry shipments from the Department of Commerce's *Current Industrial Report* (54). The data on steel mill shipments are gathered from industry questionnaires.

Glass

No comprehensive source of data was found for glass production in tonnage. Estimates for glass containers, pressed and blown glass, and flat glass were derived from separate sources. Apparent domestic consumption in tonnage for glass containers was derived from the Glass Container Manufacturer's Institute (GCMI) and the Glass Packaging Institute (55,56). In 1976, the Bureau of the Census in *Current Industrial Reports* (57) published for the first time tonnage estimates for glass container production by type of container. The ton-per-container ratio assumed by the Census was used to allocate glass container shipments between beverage and other containers for this study.

Apparent domestic consumption estimates in tonnage for pressed and blown glass products and flat glass were not available until recently when the Federal Energy Administration (now the Department of Energy) began to collect data on industrial energy usage based on a BTU-per-ton of production from representative industries. Estimates of tonnage were derived from raw materials consumed in tonnage for glass, sand, soda ash, and cullet from the Census of Manufacture's (57) "Materials Consumed by Kind" table for the pressed and blown glass industry, SIC 3229 and the flat glass industry, SIC 3211. A comparison of estimates obtained by this methodology with the DOE estimates indicates substantial agreement considering DOE accounted for only 60% of the output from the pressed and blown glass industry. End-use allocations for pressed, blown and flat glass were derived from the Census of Manufactures and from the INFORUM Model. Glass fiber for textiles was excluded from this study because of its inclusion in textiles.

A comparison of the IR&T glass materials-flow estimation procedure with the Smith/Franklin methodology indicated that both used the GCMI data for glass containers. No documentation of other glass estimates was available. However, in *A Solid Waste Estimation Procedure: Materials-Flow Approach* (27), EPA used an MRI estimate that employed a similar methodology to that used in this study.

Lead

The data from the time series in two Bureau of Mines publications, *Mineral Facts and Problems* (44) and Mineral Commodity Profiles *Lead 1977* (58), were selected for the IR&T time series. As a result of informative conversations with the lead commodity specialists at the Bureau of Mines, the methodology used to group the various lead products from the *Minerals Yearbook* categories into the *Mineral Facts and Problems* major end-use markets was altered. Batteries were segregated from the transportation end-use category and the electrical and electronic products category. Batteries, specifically storage batteries, which include batteries, grids and posts, and battery oxides, are primarily used in automobiles. They are also used to some extent in the electrical and electronic products category for standby power and emergency lighting. The time series totals for batteries were derived from the *Minerals Yearbook* (51) storage battery figures. The residual transportation end-use figure included the use of lead in bearings, solder, and weights and ballast in wheels and keels, respectively. The residual direct use of lead in transportation was allocated between automobiles and other transportation end-use based on estimates from INFORUM. The residual direct use of lead in the electrical and electronics end-use market includes the use of lead in cable coverings, solder, and brass and bronze.

The data for the ordnance and buildings and structures end-use categories were taken directly from the Bureau of Mines time series because descriptions of the markets correspond to end-use categories in the IR&T Model. Lead is used in pipes, traps and beds, sheet lead, calking lead, and solder in the buildings and structures market. In the ordnance end-use market, lead is used in the manufacture of ammunition.

Leather

No published estimates of material consumption in tonnage were found. IR&T derived estimates of leather consumption by product end-use from ton-per-dollar ratios in the Census of Manufactures (46) and from the dollar flows in the INFORUM Model.

Paper and Paperboard

Tonnage estimates of apparent consumption from the *Current Industrial Report, Pulp, Paper and Board* (59) provided the basis for the material history report for paper and paperboard. These data were compared to data in the American Paper Institute's annual report, *Statistics of Paper and Paperboard* (60). There is general agreement between Census estimates and those provided by API; however, small variations of up to 4% may exist in any given year between the sources. In this study, data directly from the Bureau of the Census is considered to be the best available source because it provides the underlying economic data of the input-output model used in this study.

Estimates for paper and paperboard employed in this study are comparable to those used in other materials-flow studies, including those by William Franklin for EPA's Office of Solid Waste and the Midwest Research Institute.

There are small differences in this procedure due to variations in definitions of product categories.

Plastics

An investigation of data sources indicated that no comprehensive source for apparent domestic consumption estimates exists for plastics by product category. Two major sources of estimates of apparent domestic consumption are the U.S. International Trade (formerly Tariff) Commission's annual publication *Synthetic Organic Chemicals* (61) and the Society of the Plastic Industry's (SPI) *Facts and Figures of the Plastics Industry* (62). A third source is McGraw-Hill's publication *Modern Plastics* (41), which uses SPI totals and allocates plastic tonnage to major market end-uses. According to an editor of *Modern Plastics*, SPI obtained estimates of plastics production and sales in 1970 from the U.S. Tariff Commission. The plastics industry considers the Tariff estimates to be unreliable because they include production data on textiles using plastic products and exclude other specific plastics categories. SPI, on the other hand, derives its estimates from a plant survey.

Due to the desire to maintain consistency between total consumption and market end-use allocations as well as expressed industry misgivings with the Tariff Commission estimates, the data from *Modern Plastics* were selected. Specific major market end-use data were derived from *Modern Plastics.* Unfortunately, a portion of plastic usage was left unaccounted for by this source, and data were only available from 1967. To fill in the gaps, an analysis of *Modern Plastics* detailed end-use estimates by resin was made to account for consumer and institutional products, i.e., luggage, medical products, records, optical goods, tools, and recreational products, machinery and other industrial equipment. Trends in plastic usage, published in *Markets for Plastics* (63), were used to fill in data gaps for earlier years. A miscellaneous category was used for plastics in agricultural applications. The other industrial applications category was used for the remaining plastics, assuming that the residual was used in adhesives, coatings and other applications that are consumed in the production of other finished materials (e.g., textiles, paints).

Although the methodology selected has shortcomings given the lack of data and the ubiquitous nature of plastics usage, these estimates are the best available. Comparing this methodology to that of William Franklin's projections for EPA's Office of Solid Waste, differences were noted. Franklin did employ *Modern Plastics* data for packaging; however, other uses were derived from a secondary source: A.D. Little's *Incentives for Recycling and Reuse of Plastics* (64). An examination of these estimates indicated that this source originally utilized *Modern Plastics* data for its estimates. The EPA estimates seem to be out of date given the fact that the study was published in 1972 and plastics usage has changed considerably in recent years.

Rubber

The only available source of apparent domestic consumption of rubber is the Rubber Manufacturers Association's publication (65). The data is divided into tire and non-tire products and the problem is to allocate rubber among non-tire market end-uses. *Rubber Age* (66) has published estimates of rubber use for footwear, mechanical goods, wire and cable, latex foam products, and other; however, there is no corresponding tonnage data available for the market end-use categories in this study. Consequently, estimates were derived from Census of Manufactures (46) data for the Fabricated Rubber Products, NEC Industry, SIC 3069.

A comparison of this methodology with William Franklin's approach for EPA indicated that although RMA data was also used, it appeared that no attempt was made to allocate non-tire rubber usage to more precise end-use categories.

Textiles

The total annual consumption figures for textiles were taken from the time series in the Textile Economics Bureau publication, *Textile Organon* (67). *Textile Organon* specifies many market end-uses for textiles, so the various end-uses were grouped and calculated according to market end-uses currently in the IR&T Model.

Wood

Estimates of total apparent domestic consumption of wood by product category end-uses were derived from the U.S. Forest Service's annual report *The Demand and Price Situation for Forest Products* (68) and another publication, *The Outlook for Timber in the United States* (42). The estimates do not include woodpulp. The product category allocations for buildings and structures, including mobile homes, furniture, consumer products, machinery and other transportation were derived from the latter source. Mobile homes are classified as buildings and structures, in order to be consistent with the revised 1972 SIC definitions. The IR&T data is based on 1973-1974 data because the Forest Service will not be updating its end-use survey until later this year. Although Forest Service data were also used by EPA, tonnage estimates were made through the use of conversion ratios. Thus, some differences can be noted in materials end-use estimates.

Zinc

The time series in two Bureau of Mines publications, *Mineral Facts and Problems* (44) and Mineral Commodity Profiles *Zinc 1977* (69), were selected for the zinc time series. The source of the brass and bronze end-use data for zinc in the government publications is the Copper Development Association's publication *Annual Data 1976: Copper Supply and Consumption 1956-1975* (50). The source of the government figures for the use of zinc in galvanizing is the American Iron and Steel Institute's *Annual Statistical Report* (38, 39). The trade association data is based on industry questionnaires.

LINKAGE TO THE ECONOMIC FORECASTING MODEL

The most difficult part of the methodology involves the linkage of physical material flows data to dollar flows in the economic model. The input-output model used in this study provides considerable variety with its 185 sector scheme. However, as with an industry-based input-output model, the estimates of dollar flows between industries are not directly related to the analysis of flows by specific materials to specific products. To illustrate the problem, flows of aluminum in an interindustry model are considered. The aluminum industry sells some aluminum directly to the motor vehicles industry and some indirectly through the metal stampings industry. The metal stampings industry sells aluminum metal stampings (e.g., fenders, hoods, trunk lids, etc.) to the motor vehicles industry and also to consumers (e.g., aluminum pots and pans). Part of the sales by the metal stampings industry to the motor vehicles industry includes stampings made from steel and other metals. It is clear from this example that it would be difficult to distinguish material-specific flows between industries from industry-specific dollar flows for the purpose of estimating the amounts of specific materials used to manufacture final products. To do so would require a very detailed, commodity-specific input-output table, and no such table of the U.S. economy exists in a form readily available for this study. Consequently, for the purpose of mapping physical material flows to interindustry transactions, a very basic assumption is made. It is assumed that interindustry transactions in dollar terms provide reasonable indicators of physical material flows, and that the relationships between the dollar flows and physical flows hold over time.

The proportionality assumption in itself does not solve the problem of distinguishing the amount of aluminum in metal stampings sold to automobiles from the amount of steel, since the relative amounts of aluminum and steel in the metal stampings sold to the motor vehicles industry can change over time. To account for this aspect, the relationship between the physical flow of aluminum used in the manufacture of motor vehicles, to the dollar transactions between the metal stampings and motor vehicles industry, is determined by a set of transactions: the sales by the aluminum industry directly to the motor vehicles industry, sales of aluminum to metal stampings, and sales of metal stampings to the motor vehicles industry. This approach, called the "path products" or "chain" approach, was developed for the purpose of estimating solid waste flows in the earlier work by IR&T for EPA, and is discussed in detail in the final report for that study (33).

The chain approach makes use of the interindustry sales (input-output) coefficients of the economic forecasting model. In the model, the dollar output of each of the 185 sectors is estimated by summing sales to other industries (i.e., intermediate demands) and sales of finished goods (i.e., final demands). Consequently, the sales by an industry i, X_i, can be shown mathematically as:

$$X_i = \sum_{j=1}^{185} a_{ij}X_j + F_i$$

where a_{ij} denotes the dollar input requirement of industry i per dollar output of industry j (X_j), and

F_i denotes the final demand for outputs of industry i.

Alternatively, the sales by each industry can be shown in matrix form, as follows:

$$\overset{X}{\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_{185} \end{bmatrix}} = \overset{A}{\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots & a_{1,185} \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots & a_{2,185} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{185,1} & a_{185,2} & a_{185,3} & \cdots & a_{185,185} \end{bmatrix}} \overset{\text{times}}{\times} \overset{X}{\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_{185} \end{bmatrix}} + \overset{F}{\begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_{185} \end{bmatrix}}$$

Here, X and F are vectors of outputs and final demands, respectively, and A is a matrix of dollar-input-per-dollar-output coefficients. In solving for the outputs of each industry, the final demand vector and 'A' matrix are given, so that

$$X = (I - A)^{-1} F$$

where $(I - A)^{-1}$ is the inverse of the identity matrix minus the A matrix. This relationship is derived algebraically from the earlier relationship, $A = AX + F$.

The terms of the inverse matrix suggest the amount by which the output of an industry is affected by the final demand for each industry's output. If we call the inverse matrix B, we can show the relationship as:

$$\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_{185} \end{bmatrix} = \begin{bmatrix} b_{1,1} & b_{1,2} & b_{1,3} & \cdots & b_{1,185} \\ b_{2,1} & b_{2,2} & b_{2,3} & \cdots & b_{2,185} \\ \vdots & \vdots & \vdots & & \vdots \\ b_{185,1} & b_{185,2} & b_{185,3} & \cdots & b_{185,185} \end{bmatrix} \times \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_{185} \end{bmatrix}$$

Hence, the output of aluminum is determined as the sum of the products of the inverse terms for the aluminum industry times the final demands for the output of each industry, i.e., X = BF. Within this formulation, the product of the inverse term for the aluminum industry times final demand for motor vehicles, reflects not just the aluminum used in the manufacture of motor vehicles (including the aluminum in metal stampings purchased by the motor vehicles industry), but all indirect impacts of motor vehicles sales to final demand on aluminum industry outputs. To illustrate, the motor vehicles industry requires a number of aluminum products to provide support for the manufacture of motor vehicles (e.g., light bulbs, tools, and other equipment). Such articles or tools are not incorporated in the final products, but are extended during the production process. The inverse terms also indicate impacts on the aluminum industry that are completely removed from motor vehicle manufacturing. The motor vehicles industry buys products from industries that require products made of aluminum in their own productive processes, and these impacts are also reflected in the aluminum to motor vehicles inverse term.

A simplified approach for relating physical materials flows to dollar flows would be to associate the material flows with the products of the inverse terms times final demands. For this purpose, the amount of aluminum actually incorporated in the motor vehicle is assumed to be proportional to the relationship of the inverse term to output over time. This is the apporach used in the study by Research Triangle Institute, described in Section 1 (32). The limitations of the approach are primarily concerned with the problem of differentiating the amount of materials incorporated in final products, from materials incorporated in other products expended during their manufacture, the proportions of which are likely to change over time.

However, the differentiation can be made using the uninverted input coefficients, since the inverse is a formal power series expansion of the input coefficients. That is:

$$\begin{aligned} B &= (I - A)^{-1} \\ &= I + AB \\ &= I + A + A^2 B \\ &= I + A + A^2 + A^3 + \dots \end{aligned}$$

Written algebraically, we have:

$$b_{ij} = 1 + a_{ij} + \sum_k a_{ik}a_{kj} + \sum_k \sum_l a_{ik}a_{kl}a_{lj} + \dots$$

Since all of the coefficients are less than or equal to 1.0, the products of the coefficients times other coefficients get successively smaller as the expansion moves to the right in this equation. Hence, an approximation of the inverse can be obtained after summing several of the elements of the series. Furthermore, through disaggregating the inverse terms into components comprised of individual A matrix coefficients, the dollar flows that are the best indicators of physical material flows to particular products can be identified. By isolating these "chains," the sequences of dollar flows that reflect the flows of materials that are not incorporated in a subject final product, can be removed. These include input requirements of industries supplying raw materials (e.g., purchases by the mining and agriculture sectors), service costs (e.g., transportation, repairs, and insurance), and overhead and manufacturing costs (e.g., office supplies, machine tools, electricity and other fuels).

The selection of specific chains also avoids the prorating and aggregation errors inherent in input-output analysis. Such problems occur when the flow of material from one industry to another continues on to third and fourth industries which purchase intermediate products from the second industry that contains different proportions of the material. For example, the proportion of aluminum metal stampings to steel metal stampings used by the motor vehicles industry is different than the proportions used in the manufacture of pots and pans.

The selection of chains to be used as indicators of materials-flows is necessarily based on judgment. It is desirable, however, to tighten the causal connection between final product use and material composition, by eliminating as many spurious chains as possible. Because of the enormous number of chains contained in a 185-sector input-output table, it is not possible to examine every chain in a material flow. Consequently, for this study only major direct and indirect flows for each material to each product category were selected.

The selection procedure has theoretical foundations that are discussed at length in the previous IR&T study (33). The report for that study demonstrates methods for adjusting flows in the input-output model to estimate solid waste emanating from households. For this study, the major chains relating materials to all product end-uses were selected.

In the household waste study, it was shown that the economy, as represented by an input-output table, appears to consist of a relatively small number of major dependencies and a very large number of distant effects. This is demonstrated in Table 32, which shows that relatively few chains are required to account for most of the output of sectors producing the materials relevant to this study. The number of chains required to account for all flows greater than half of one percent of output is considerably larger, but still manageable. By nearly doubling the number of chains considered, all flows accounting for more than two-tenths of a percent of total output would be included, but this addition would add little to the accuracy as evidenced by the small difference in coverage at the two thresholds.

The chains selected for use in the study are presented in detail in the appendix; however, an example for one material, textiles, is shown in Figure 4. The numbers in this diagram refer to sectors of the input-output model.

ESTIMATING FUTURE SOLID WASTE

The chains selected for each material flowing to each end-use product are used to estimate future material flows. As the structure of the economy changes with materials substitution and technology innovations, the input-output coefficients take on new values affecting the values of the chains. The input-output coefficients change over time according to logistics curves estimated on the basis of historical trends. These changes are adjusted in some cases on the basis of engineering data and opinions of industry experts. The relative change in the values of the chains are used to estimate implied changes in materials used for the manufacture of each end-use product.

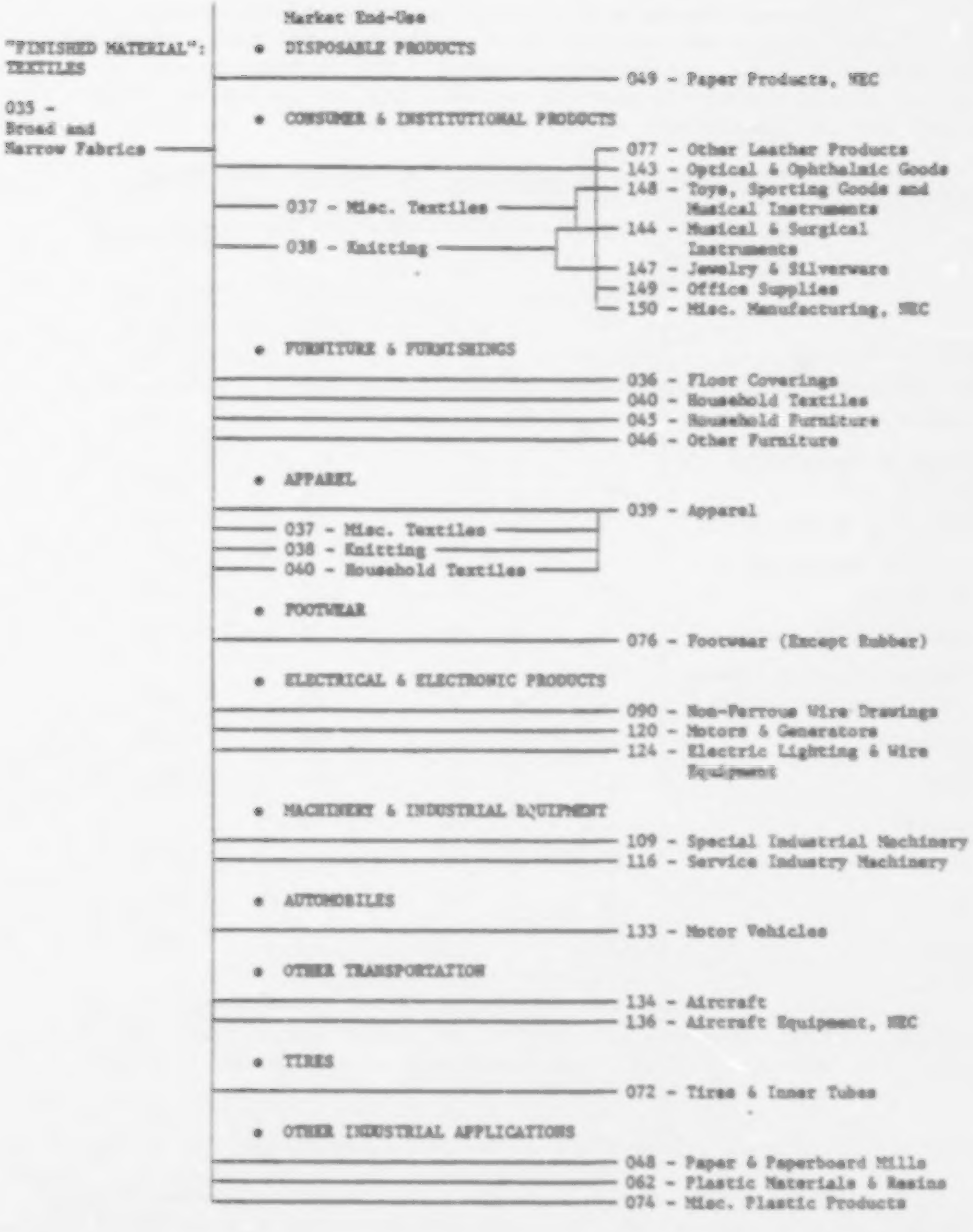
TABLE 32. PATH PRODUCTS BY MATERIAL FOR VARIOUS THRESHOLDS*

	Number of Chains			
		Threshold		
INFORUM Sector Number and Name	Accounting for 75% of Output	.005 of Output	.002 of Output	Difference in Coverage Between .005 and .002
41 Lumber	5	23	40	.005
48 Paper & Paperboard Mills	14	82	125	.014
50 Building Paper Mills	7	19	37	.005
62 Plastic Materials & Resins	35	96	180	.025
63 Synthetic Rubber	4	38	75	.011
75 Leather Tanning/Industrial Leather Goods	2	14	22	.003
78 Glass	5	39	65	.008
83 Steel	13	58	92	.011
84 Copper	21	48	78	.009
85 Lead	20	84	177	.029
86 Zinc	35	99	209	.034
87 Aluminum	18	57	103	.015
TOTAL	179	657	1,203	

* Calculated using input coefficients of the input-output table, which represent the amount of sales of an industrial sector to other industries per dollar of selling industry output.

Source: International Research and Technology Corporation.

Adjustments are then made to account for processing losses (i.e., new scrap) using technological data, and for the import and export of finished products on the basis of import and export estimates from the economic forecasting model. In most cases, it is assumed that the materials composition of imports is comparable to that of products pro-


Market End-Use
"FINISHED MATERIAL": TEXTILES
033 - Broad and Narrow Fabrics
• DISPOSABLE PRODUCTS
049 - Paper Products, NEC
• CONSUMER & INSTITUTIONAL PRODUCTS
037 - Misc. Textiles
038 - Knitting
077 - Other Leather Products
143 - Optical & Ophthalmic Goods
148 - Toys, Sporting Goods and Musical Instruments
144 - Musical & Surgical Instruments
147 - Jewelry & Silverware
149 - Office Supplies
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
036 - Floor Coverings
040 - Household Textiles
045 - Household Furniture
046 - Other Furniture
• APPAREL
037 - Misc. Textiles
038 - Knitting
040 - Household Textiles
039 - Apparel
• FOOTWEAR
076 - Footwear (Except Rubber)
• ELECTRICAL & ELECTRONIC PRODUCTS
090 - Non-Ferrous Wire Drawings
120 - Motors & Generators
124 - Electric Lighting & Wire Equipment
• MACHINERY & INDUSTRIAL EQUIPMENT
109 - Special Industrial Machinery
116 - Service Industry Machinery
• AUTOMOBILES
133 - Motor Vehicles
• OTHER TRANSPORTATION
134 - Aircraft
136 - Aircraft Equipment, NEC
• TIRES
072 - Tires & Inner Tubes
• OTHER INDUSTRIAL APPLICATIONS
048 - Paper & Paperboard Mills
062 - Plastic Materials & Resins
074 - Misc. Plastic Products

Source: International Research and Technology Corporation.

Figure 4. Material flow paths (chains) selected for textiles.

duced domestically. For some products, including automobiles, it was possible to modify this assumption on the basis of published data. In these cases, domestic trends in materials use were applied to estimate future compositions.

Solid waste generation by material product category is then estimated. Estimates are derived through the application of two adjustment factors: one to estimate the amount of material lost by wear or other dissipative processes before its final disposal as solid waste (the "disappearing" fraction), and the other to estimate scrappage as a function of product age. Diversions from the material flows include the permanent storage of books in libraries and tissue paper disposed of in municipal sewer systems. Time lags between purchase and disposal of products are estimated using averages, normal probability distributions, or step functions.

The solid waste estimates are adjusted to account for assumed recycling levels, based on analyses of technological and economic trends. The quantity of waste material that is recycled is comprised of two components: new and old scrap. New scrap constitutes materials discarded during the manufacturing process, while old scrap stems from post-consumer waste. Both are computed on the basis of assumed recycling rates for each material and product category.

Net solid waste disposals are the unrecycled residuals from discards. These quantities are distinguished by disposal sector according to product category. For example, newspapers are included in residential and commercial wastes, scrap automobiles are included in transportation wastes, and scrap machinery is an industrial waste.

LIMITATIONS

A major limitation of the methodology is that materials-flow in the economic model is not sensitive to assumptions regarding recycling rates and product lifetimes. The methodology deals with solid waste generation, disposal, and recycling in a partial equilibrium framework, taking neither the direct impact of recycling on the demand for virgin materials, nor the input requirements, including labor, of the recycling (i.e., secondary materials) industry into account. This limitation could be partially corrected by making the change in some input-output coefficients a function of recycling rates. The result would affect outputs of key industries, including forestry products, ferrous ore mining, and energy. The economic model would automatically account for impacts on other economic activities, including employment. However, the problem is compounded due to the aggregation of primary and secondary production for a number of sectors in the economic model, notably the steel and other metals industries. In these cases, economic sectors would have to be disaggregated through the inclusion of additional rows and columns in the input-output table. This would be a difficult task, but has the advantage of providing additional detail for estimating impacts of recycling and impacts of other assumptions.

A second limitation of the approach is that it provides national estimates only. To assist solid waste managers and policy planners, it would be desirable to estimate regional and municipal solid waste loads. Regional projections reflecting economic and social variables, and technological change factors could assist in the design and implementation of resource recovery incentives and facilities.

SECTION 5

RECOMMENDATIONS

For the purpose of estimating specific regional trends, it would be possible to expand to some extent on the methodology presented here. For example, the Consumer Expenditure Surveys conducted by the Bureau of Labor Statistics (35) provides estimates of spending on specific product categories, with regional detail by Standard Metropolitan Statistical Area. These data, collected every ten or twelve years since 1888, could provide a starting point for regional analyses if supplemented with information regarding resource recovery at the regional level.

In the analysis presented here, an attempt has been made to expand on the number of materials and product categories considered, and to include estimates of waste emanating not just from the residential, commerical and institutional sectors of the economy, but also those from industrial and construction activities, and from demolition and scrapped transportation equipment. It has been shown that while the residential and commercial waste load is quite substantial, the wastes emanating from demolition activities are equally so. Certainly, large components of residential and commercial wastes can be recovered more readily than those from demolition, since the bulk of the latter is composed of relatively unrecyclable concrete. In considering the extent of future disposal site requirements, the growth in replacement construction is an important element.

To complement the analysis of wastes from these sectors, it is important to recognize the potential growth in wastes emanating from activities that were not considered in this study. These include mining and agricultural wastes, and the sludges and ash collected in attempts to reduce pollution from industrial sources. The latter is likely to become a major factor given the timetables for compliance with more stringent standards in a number of areas. Disposal of hazardous wastes is a particularly significant area of concern, given the recent Love Canal and "Valley of the Drums" incidents.

Gross estimates of the quantities of some of these waste categories are currently generated by the Strategic Environmental Assessment System (SEAS), which includes the same economic model used in the IR&T analysis of solid waste. Using the economic assumptions of the IR&T Reference Scenario, along with assumptions regarding compliance with pollution abatement standards and penetrations of new energy conversion technologies, the SEAS model produced estimates of future solid waste shown in Table 33. Large portions of the projected waste loads stem from surface oil shale mining, uranium extraction, gasification and liquefaction of coal, and dry scrubbing for the abatement of sulfur oxide emissions from electric utilities. It is clear that the emergence of these energy technologies is going to compound the solid waste problem.

Municipal solid waste managers will not, of course, be concerned with most of these solid waste categories, except to the extent that competing demands for landfill areas develop. Of more interest, perhaps, are the projected trends in combustible versus non-combustible solid waste. The growth in the combustible portion is comparable in all five scenarios; about two percent per year. By 1990, these wastes may provide an alternative through the use of energy recovery systems, to high priced fossil fuels and landfills. Reductions in the non-combustible portion, either through resource recovery or increased product life, would provide similar energy saving opportunities given the relatively larger energy requirements for the fabrication of primary materials. Increasing costs of land for the disposal of these wastes may add extra incentives for resource recovery.

To estimate the impacts of rising costs in land, fossil fuels, and primary materials on the extent of future recycling would require a detailed economic analysis that takes the costs of resource recovery and the relative prices of primary and secondary materials into account. Such a methodology could be developed to expand on the analysis presented here. The need to specify future recycling rates as assumptions could be diminished, and better analysis of interindustry transactions and their effects on output, employment, and investment activities could be achieved.

TABLE 33. SEAS PROJECTIONS OF SOLID WASTE BY CATEGORY, 1975-1990 (Million Metric Tons)

Category	1975	1990	Avg. Annual % Growth
Combustible Biomass	0.0	6.9	--
Non-Combustible Waste From Pollution Abatement and Energy Conversion	80.6	439.9	12.0
Mining Wastes	66.6	200.6	7.6
Industrial Sludge	8.3	58.5	13.9
Sewage Sludge	2.8	4.5	3.1

Source: Technology Assessment Modeling Project, U.S. Environmental Protection Agency.

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APPENDIX

INTRODUCTION

The Appendix contains four sections that describe the base line data inputs used in the Reference Scenario for this study. The first section describes the sources of data for each material, adjustments made to the data, historical time series tables, and material flow diagrams from the production stage to the consumption stage. The second section provides a series of diagrams that display the interindustry flows of materials by product category end-use. The third section briefly describes the sources of the product lifetime assumptions and the fourth section provides an account of the Recycling Assumptions and their data sources.

MATERIALS DATA BASE AND FLOW DIAGRAMS

For each of the materials analyzed in this study, historical production data in tonnage were obtained from government and industry sources. The production data provide the basis for the materials-flow analysis in which materials are traced through the stages of production, consumption and finally, disposal. The production data by material are adjusted for exports and imports to estimate apparent domestic consumption. The apparent consumption of each material is then divided among the appropriate product end-use categories to determine the quantities of materials that eventually enter the waste stream. These material allocations were derived from the same government and industry sources, although in some cases allocations were derived using the input-output table of the economic model. The time series data is presented in tabular form, showing control totals for each year. For the ferrous and nonferrous metals data, adjustments were made to include new (prompt) scrap, since the methodology separates new scrap from each material. The historical time series input data, listed in short tons, is converted into metric tons to conform with EPA specifications for reporting. Since the input-output model uses 1971 as the base year, time series for the years 1960-1971 are displayed. However, some production data for later years (1972-1976) are included for selected materials and product end-use categories (e.g., beverage containers and automobiles) when relevant.

For each material, a diagram depicting the flows of materials from production to consumption in the year 1971 is included. Each diagram shows the apparent domestic consumption estimate and allocations to various product categories; new scrap adjustments; foreign trade adjustments; and net material consumption by product category. Hence, the materials-flow diagrams outline the methodology for the year 1971 based on historical data.

It should be noted, however, that this methodology is also used for forecast years. Projections of the material flows are made on the basis on inter-industry sales coefficients in the input-output model, thus accounting for structural relationships within the economy, materials substitution, technological change, and economic growth within a consistent forecasting framework. The following is a discussion of the derivation of production data and allocations to market end-use as defined by sectors of the input-output model.

Aluminum

Time series data for aluminum were available from two Bureau of Mines publications, *Mineral Facts and Problems* (44) and Mineral Commodity Profiles *Aluminum 1977* (47). The figures in the government time series on the end-use pattern were similar to those published in the Aluminum Association's *Statistical Review* (48).

After examination of the Bureau of Mines definitions of end-use categories, ten end-use categories were chosen for aluminum including beverage containers, other packaging and containers, household durables, furniture, consumer and institutional products, machinery and industrial equipment, electrical and electronic products, buildings and structures, automobiles and other transportation.

The Bureau of Mines definition of the packaging and container end-use included the use of aluminum in flexible packaging, semi-rigid food containers, foil, cap and closures, metal cans, tabs and ends, and composite cans. This total figure was allocated between the two end-use categories, beverage containers and other packaging and containers. The source of the figures for the aluminum beverage containers was the Aluminum Association's *Statistical Review* (48). The residual aluminum after segregating the beverage container end-use was allocated to the other packaging and container category.

The consumer durables product category as defined by the Bureau of Mines, included the use of aluminum in refrigerators, air conditioners, washing machines, furniture, cooking utensils, small appliances, and personal and recreational products. Thus, the end-use category included three end-use categories specified in this study. The total was allocated to household durables, furniture and consumer and institutional products based on investigation of the 1972 and 1967 Census of Manufactures (46), the INFORUM model, and product category estimates in the Aluminum Association's *Statistical Review* (48).

The Bureau of Mines transportation end-use described the use of aluminum in automobiles, including pistons, automatic transmission parts, trim, air conditioning, electrical uses, body, brakes, steering and metallic paint. The high strength-to-weight ratio of aluminum makes it valuable in any carrier, and this factor has been important in the manufacture of aircraft parts. Trucks, buses, trailers, and semi-trailers account for a significant portion of aluminum sheet and extrusions in this end-use. Aluminum is also used in commercial and naval marine, rail, motor scooters, air cushion vehicles and cargo containers. The Aluminum Association's *Statistical Review* reported data on the use of aluminum in automobiles was employed for this end-use and the residual of the Bureau of Mines total transportation category was the other transportation end-use category figure.

The other Bureau of Mines product categories included items that are consistent with product categories specfied in this study. In the buildings and structures end-use category, the category includes the use of aluminum in residential siding, doors and windows, roofing, awnings, canopies, heating and ventilation applications, curtain walls, screen frames and screening, bridge rails and guard rails, pre-engineered structures, and other bridge, street and highway uses. The electrical and communication end-use includes steel, reinforced aluminum cable that has replaced the use of copper in high transmission lines, and power transmission and distribution towers that account for a large portion of aluminum shipped to the communications market. Electrical use also includes base and insulated wire and cable, rigid conduit and electrical metallic tubing, telephone cable, electrical machinery, and equipment, lighting fixtures and electric lamps. In the last end-use category, machinery and industrial equipment, aluminum is used in special industrial and agricultural machinery, materials handling equipment, irrigation pipe, and chemical and metallurgical industries.

The material history for aluminum is presented in Table A-1 by product category. The time series is relatively short for beverage containers and other packaging and containers due to the short product lifetimes. The second reason for the short time series is the lack of specific data on these product categories. The estimates in the table by product category also include new scrap. Figure A-1 depicts the material flow of aluminum from production to final waste stream, including new scrap and net import adjustments to the data.

Concrete

Consumption of all concrete is attributed to the buildings and structures product end-use category. The source of data is the MIT study, *An Investigation of the Potential for Resource Recovery from Demolition Waste* (45). The historical time series data are presented in Table A-2. A material flow diagram is not presented for concrete because of the sole product end-use, buildings and structures.

Copper

The *Mineral Facts and Problems* (44) and *Copper 1977* (49), both published by Bureau of Mines, are sources of the material history time series data. The source of the government end-use time series data is the Copper Development Association's *Annual Data 1976: Copper Supply and Consumption, 1956-1975* (50) and the *Minerals Yearbook* (51) data on specific copper products, such as insulated wire and cable.

Eight product categories were selected after an investigation of the Bureau of Mines definitions, used to verify the correspondence of source end-use categories to end-use categories in the economic model. The eight product categories include electrical and electronic products, household durables, TABLE A-1. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR ALUMINUM (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Beverage Containers	0	0	0	0	0	0	0	0	261	314	436	460
Other Packaging & Containers	0	0	0	0	0	0	0	0	258	275	293	308
Consumer/Institutional Prod.	137	164	192	167	206	230	259	231	266	287	255	271
Furniture & Furnishings	37	44	53	45	57	63	70	63	74	78	70	74
Household Durables	74	89	104	92	112	126	141	127	149	158	139	148
Electrical/Electronic Prod.	269	320	372	326	411	527	671	632	663	703	676	721
Machinery/Industrial Equip.	166	197	230	212	247	281	338	313	342	346	301	327
Automobiles	191	228	277	262	295	348	403	361	437	421	354	449
Other Transportation	286	340	417	393	442	523	603	540	561	557	412	460
Buildings & Structures	560	666	791	732	862	933	1,024	975	1,136	1,171	1,117	1,414
Other Industrial Appl.	0	0	0	0	0	0	468	514	555	530	393	369
TOTAL	1,720	2,048	2,436	2,229	2,632	3,031	3,977	3,756	4,702	4,840	4,445	5,001

Source: *Mineral Facts and Problems*, 1970 and 1975 editions, Bureau of Mines, U.S. Department of Interior.
Aluminum 1977, Mineral Commodity Profiles, U.S. Department of Interior, 1977.
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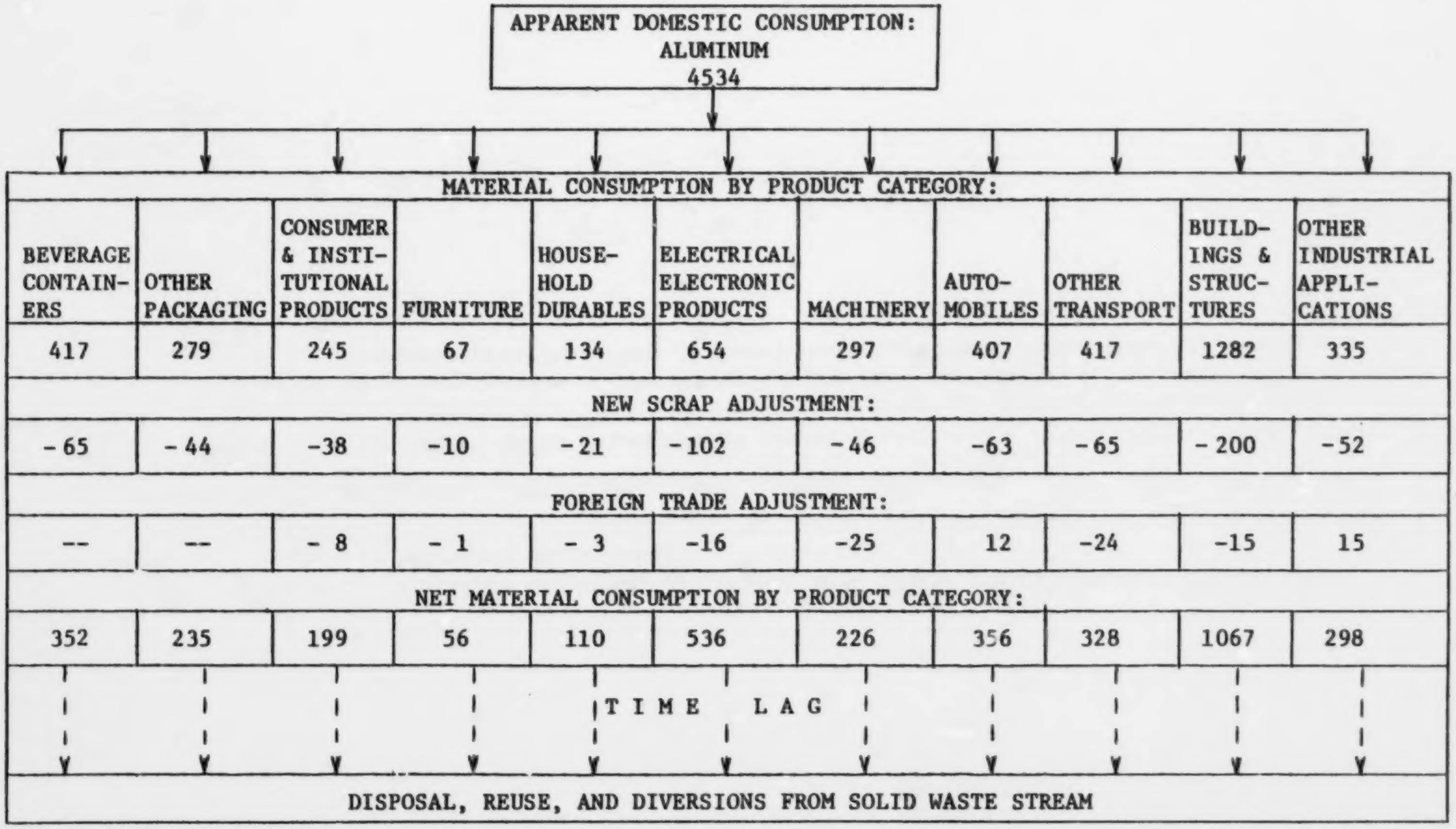


APPARENT DOMESTIC CONSUMPTION: ALUMINUM 4534

	BEVERAGE CONTAINERS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	HOUSEHOLD DURABLES	ELECTRICAL ELECTRONIC PRODUCTS	MACHINERY	AUTOMOBILES	OTHER TRANSPORT	BUILDINGS & STRUCTURES	OTHER INDUSTRIAL APPLICATIONS
MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	417	279	245	67	134	654	297	407	417	1282	335
NEW SCRAP ADJUSTMENT:	- 65	- 44	-38	-10	- 21	- 102	- 46	-63	- 65	- 200	-52
FOREIGN TRADE ADJUSTMENT:	--	--	- 8	- 1	- 3	-16	-25	12	-24	-15	15
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	352	235	199	56	110	536	226	356	328	1067	298

TIME LAG

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

Source: International Research and Technology Corporation

Figure A-1. Material flow diagram of aluminum in 1971 (10^3 metric tons).

TABLE A-2. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR CONCRETE
(Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Buildings & Structures	282,210	288,777	300,426	314,450	329,256	338,000	343,977	336,948	359,052	372,031	357,464	378,139

Source: *An Investigation of the Potential for Resource Recovery from Demolition Wastes*, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1976.

buildings and structures, machinery and industrial equipment, automobiles, other transportation, ordnance, and consumer and institutional products. In two instances, the general product categories (electrical and electronic products and transportation), defined by the Bureau of Mines included more specific end-use than specified by the economic model.

The Bureau of Mines electrical and electronics end-use category includes the use of copper in electrical apparatus, such as electric motors, power generators, motor generator sets, dynamotors, fans, blowers and industrial controls. Copper is also a component in electrical transmission, distribution equipment, lighting and wiring equipment, electronic navigation and communications, including electronics, telephone and telegraph wires and cables. The electrical category also includes household appliances, knives, hairdryers, toasters, blenders, coffeemakers, and frying pans. Thus, the electrical and electronics market end-use includes the various electrical uses of copper as well as the specific use of copper in household durables. Estimates of the household durables product category and the electrical and electronic product category were derived by allocating the total electrical figure among the two end-uses according to the INFORUM model.

The Bureau of Mines figures on machinery and industrial equipment, buildings and structures, ordnance, and consumer and institutional products did not require adjustment because the definitions of the product categories corresponded to the solid waste end-use categories. Buildings and structures included the use of copper in building, construction, roofing, brass, and bronze decorations, and utilitarian items for public buildings and private homes. According to the Bureau of Mines, the end-use category machinery and industrial equipment includes the use of copper in household and commercial air conditioning, farm machinery, and components in sea water desalination distillation plants and pollution control equipment. The ordnance end-use category description includes the use of copper in the manufacture of munitions and armaments. The consumer and institutional products, as specified by the Bureau of Mines, includes the use of copper in coinage, chemical pigments and jewelry. Copper is also used extensively in watches, clocks, microscopes, projectors and many types of gauges.

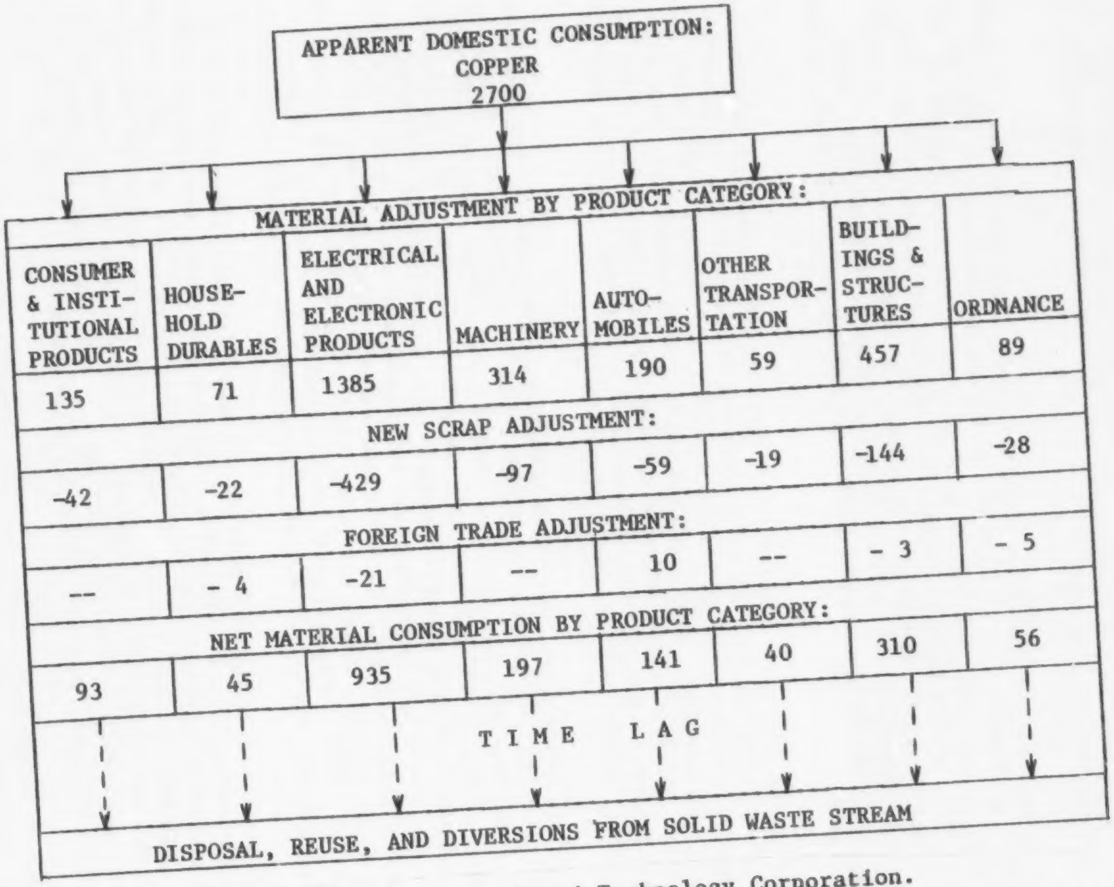
The last category defined by the Bureau of Mines is the transportation category which includes the numerous applications of copper in the automobile industry, railroad transportation, airplane manufacture, and in marine applications. The use of copper, especially in automobiles, results from the trend toward greater convenience and comfort such as power windows, seats, brakes, steering, and air conditioning, and also from more utilitarian uses in radiators, heaters and defrosters, bearings, brushings, carburetors, oil lines and wiring. The Bureau of Mines transportation category includes the use of copper in automobiles and other modes of transportation, two end-use categories specified in the solid waste model. The automobile and other transportation estimates were derived by allocating the total figure between the two end-uses based on the INFORUM economic data.

The complete time series data are presented in Table A-3. The estimates include new scrap, although government sources do not include new scrap. It is necessary to include new scrap due to the methodology which adjusts

TABLE A-3. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR COPPER (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Consumer/Institutional Prod.	46	50	51	41	37	154	176	146	149	164	150	150
Household Durables	51	52	56	58	69	74	85	81	75	87	80	81
Electrical/Electronic Prod.	955	997	1,071	1,107	1,295	1,416	1,622	1,532	1,440	1,641	1,515	1,532
Machinery/Industrial Equip.	365	382	410	440	452	442	458	301	346	368	364	352
Automobiles	188	197	211	229	242	247	247	158	210	216	188	209
Other Transportation	62	65	70	76	80	83	81	52	70	71	62	70
Buildings & Structures	480	500	538	565	608	602	594	402	458	494	476	509
Ordnance	136	142	154	159	174	65	263	272	238	249	173	100
TOTAL	2,283	2,385	2,561	2,675	2,957	3,083	3,526	2,944	2,986	3,290	3,008	3,003

Source: *Copper 1977*, Mineral Commodity Profiles, U.S. Department of Interior, 1977.
Mineral Facts and Problems, 1970 and 1975 editions, Bureau of Mines, U.S. Department of Interior.
Annual Data 1976: Copper Supply and Consumption; 1956-1975, Copper Development Association, 1976.


APPARENT DOMESTIC CONSUMPTION:
COPPER
2700
T I M E L A G
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

	CONSUMER & INSTI-TUTIONAL PRODUCTS	HOUSE-HOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTO-MOBILES	OTHER TRANSPOR-TATION	BUILD-INGS & STRUC-TURES	ORDNANCE
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:	135	71	1385	314	190	59	457	89
NEW SCRAP ADJUSTMENT:	-42	-22	-429	-97	-59	-19	-144	-28
FOREIGN TRADE ADJUSTMENT:	--	- 4	-21	--	10	--	- 3	- 5
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	93	45	935	197	141	40	310	56

Source: International Research and Technology Corporation.

Figure A-2. Material flow diagram of copper in 1971 (in 10^3 metric tons).

material flows to exclude new scrap. Figure A-2 shows the new scrap adjustment as well as the other adjustments such as foreign trade or conversion loss adjustments in the methodology during the flow of material from production to consumption to disposal.

Ferrous Metals

The total consumption estimates for iron and steel allocated by product category are now available in the Bureau of Mines publication *Mineral Facts and Problems* (44). These estimates are based on the American Iron and Steel Institute's data on steel mill shipments and the Department of Commerce data on foundry shipments (38, 39, 54).

After examining the American Iron and Steel Institute's data on markets for steel mill shipments and the Bureau of Mines definitions of product categories, a methodology was derived to include twelve end-use markets in the time series. The twelve product categories are buildings and structures, machinery, electrical and electronic products, household durables, furniture and furnishings, consumer and institutional products, automobiles, other transportation, beverage containers, other packaging and containers, ordnance and miscellaneous.

The Bureau of Mines categories of transportation, cans and containers, and others, were disaggregated to reflect other end-uses. The transportation end-use category includes iron and steel used in automobiles, trailers, van-type vehicles, van coaches, truck trailer parts and accessories. The automobile and other transportation end-use categories were segregated from the general transportation category using the data in the American Iron and Steel Institute's (AISI) *Annual Statistical Report* (38,39).

The cans and containers end-use category was specified in the American Iron and Steel Institute's report and *Mineral Facts and Problems*. Using two Department of Commerce publications, the *Current Industrial Report* (70) and *Containers and Packaging* (71) on beverage containers, steel beverage containers were segregated from the general category and the remaining containers were allocated to the other packaging and container end-use market. The other packaging and container category includes the use of steel in sanitary and general lined cans, crowns, caps, and other closures, steel barrels and drums, shipping pails for paint and petroleum, compressed gas cylinders, bailing, blending, strapping and tying strips, and miscellaneous boxes and containers.

The appliances and equipment end-use category includes the use of iron and steel in furniture, office furniture, business machines, restaurant cooking and dish-washing equipment, soda fountain equipment, floor and wall cleaning equipment, commercial dry cleaning equipment, hospital and surgical equipment, professional and scientific equipment, sporting goods, toys, signs and ordnance. These uses were accordingly assigned to the consumer and institutional products, furniture, and household durables categories using AISI data.

The Bureau of Mines definitions for the product categories, buildings and structures, machinery, and electrical and electronic products were consistent with the end-use markets in this study. The data were taken directly from the Bureau of Mines publication. A brief description of the categories will be given to show the consistencies between the sources and the end-uses defined in the study.

The buildings and structures end-use category of iron and steel includes the use of these metals in apartment buildings, dormitories, hotels, industrial buildings, commercial warehouses, offices, lofts, department stores, restaurants, government buildings, schools, hospitals, churches, and bus and air terminals. The steel mill shipments are also used in dams, reservoirs, bridges, tunnels, guard rails, transmission towers, water works, power plants and electric light structures.

The machinery end-use category includes the use of steel mill products in agricultural machinery (e.g. combines, pickers, and plows) and industrial machinery (e.g. industrial trailers, tractors, boilers, industrial engines, conveyors, escalators, cranes, elevators, and fork lifts). Iron and steel are also used in ball bearings, roller, plain and tapered bearings, mechanical power transmission equipment, and attrition mills and valves. Pipes, tubes and equipment used in oil and gas industries are also accounted for in this end-use market.

In the electrical end-use category, iron and steel data include use of material in turbo-generators, generator type steam turbines, motor powered generators, electric lighting equipment, flashlights, floodlights and traffic lights.

The household durables end-use category includes the use of iron and steel in cooking and space heating stoves, refrigerators, freezers, room air conditioners, household laundry equipment, dishwashers, enamelware (i.e., pots, pans, pails and tinware), galvanized ware, cutlery and table flatware. Miscellaneous uses of steel were calculated to be the residual.

Table A-4 shows the historical time series production data of ferrous metals including appropriate adjustments to general categories to disaggregate them into detailed end-uses. It should be noted that the government and trade association data excludes new scrap. New scrap is included in the data inputs from Table A-4. Figure A-3 follows this table and shows the flow of the ferrous metals from production to consumption for the year 1971.

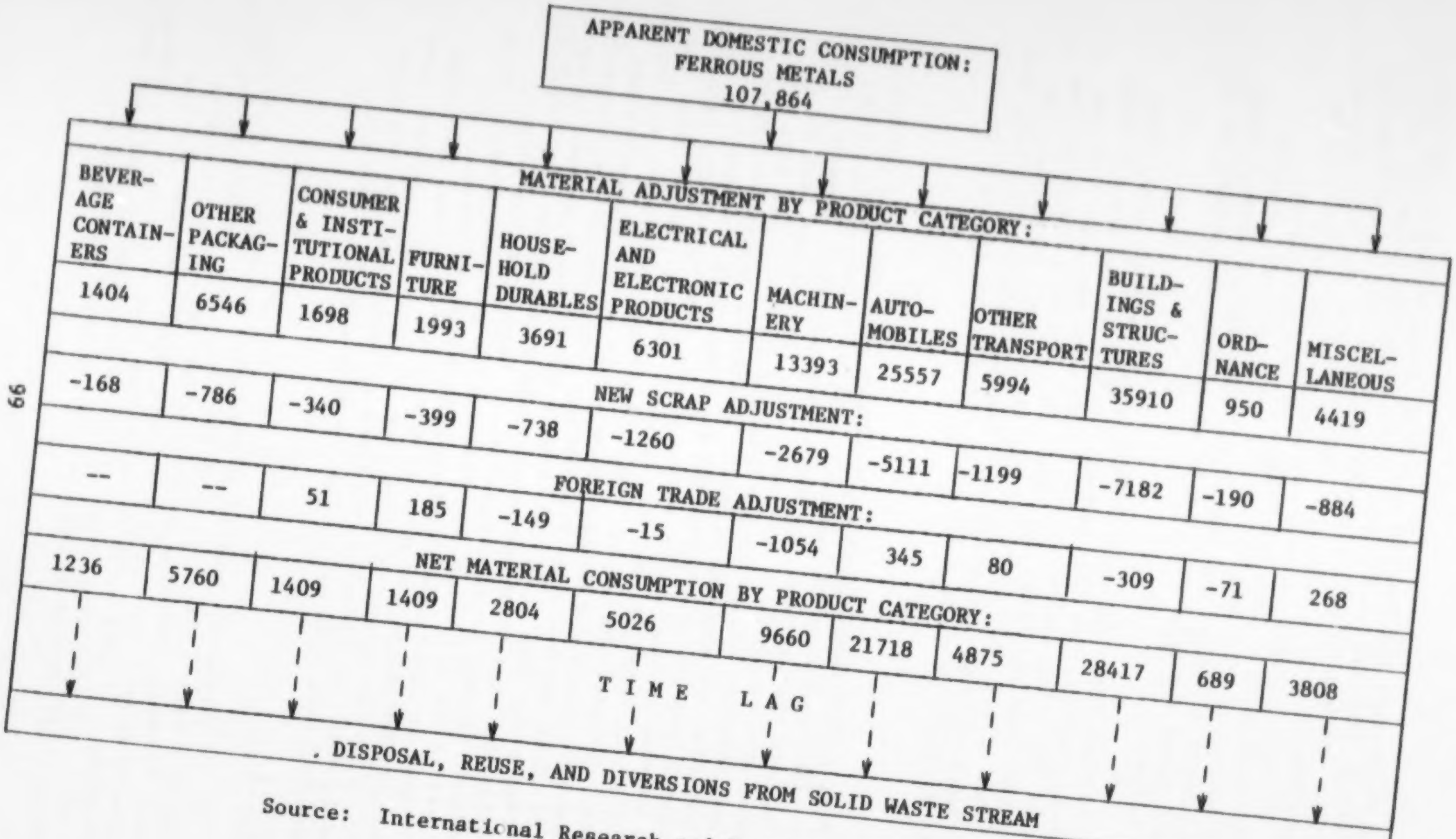
Glass

No historical time series data in tonnage was available for glass by product category. Apparent domestic consumption data in tonnage for glass containers were derived from the Glass Container Manufacturer's Institute and the Glass Packaging Institute time series (55,56). The Bureau of the Census *Current Industrial Report* (57) provided tonnage estimates for glass containers (1976) by type of container and Census ton-per-container ratios were used to allocate glass container shipments between beverage and other packaging and containers.

TABLE A-4. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR FERROUS METALS
(Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Beverage Containers	0	0	0	0	0	0	0	0	0	1,572	1,980	1,930
Other Packaging & Containers	0	0	0	0	0	0	0	0	0	6,701	7,020	6,843
Consumer/Institutional Prod.	1,597	1,520	1,604	1,706	1,907	2,069	2,133	1,966	2,078	2,049	1,960	1,872
Furniture & Furnishings	2,044	1,884	1,989	1,979	2,212	2,482	2,474	2,359	2,511	2,390	2,205	2,197
Household Durables	2,746	2,675	2,823	3,138	3,509	3,723	3,925	3,538	4,070	4,098	4,001	4,069
Electrical/Electronic Prod.	4,986	4,865	5,289	5,759	6,496	7,547	7,699	7,119	7,796	7,378	7.030	6,948
Machinery/Industrial Equip.	11,098	10,339	11,239	12,237	14,460	16,036	16,359	14,455	15,827	16,422	14,938	14,766
Automobiles	20,644	18,245	21,047	23,211	26,026	29,419	27,146	25,039	30,142	28,755	23,526	28,177
Other Transportation	4,532	3,475	4,311	5,445	6,507	7,355	8,109	6,656	6,616	6,745	6,636	6,609
Construction	28,321	27,433	28,291	30,556	33,968	38,603	38,249	35,990	40,422	39,525	39,126	39,592
Ordnance	173	191	264	310	231	322	769	1,847	2,430	2,036	1,414	1,047
Miscellaneous	2,980	2,747	2,868	3,083	3,404	4,042	4,039	3,708	3,991	4,235	4,835	4,872
TOTAL	79,121	73,374	79,725	87,424	98,720	111,598	110,902	102,677	115,883	121,906	114,671	118,922

Source: *Mineral Facts and Problems*, 1970 and 1975 editions, Bureau of Mines, U.S. Department of Interior.
Annual Statistical Report (1960, 1970, 1976), American Iron and Steel Institute.
Containers and Packaging, Quarterly Annual Report, Bureau of Domestic Commerce, U.S. Department of Commerce.
Current Industrial Reports, Series M34D, Metal Cans, Summary for 1976, Bureau of the Census, U.S. Department of Commerce.



APPARENT DOMESTIC CONSUMPTION:
FERROUS METALS
107,864
TIME LAG
. DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

	BEVERAGE CONTAINERS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	HOUSEHOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTOMOBILES	OTHER TRANSPORT	BUILDINGS & STRUCTURES	ORDNANCE	MISCELLANEOUS
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:	1404	6546	1698	1993	3691	6301	13393	25557	5994	35910	950	4419
NEW SCRAP ADJUSTMENT:	-168	-786	-340	-399	-738	-1260	-2679	-5111	-1199	-7182	-190	-884
FOREIGN TRADE ADJUSTMENT:	--	--	51	185	-149	-15	-1054	345	80	-309	-71	268
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	1236	5760	1409	1409	2804	5026	9660	21718	4875	28417	689	3808

Source: International Research and Technology Corporation.

Figure A-3. Material flow diagram of ferrous metals in 1971 (in 10^3 metric tons).

Estimates of tonnage for pressed and blown glass products and flat glass were derived from tonnage figures of raw materials consumed (i.e., glass, sand, soda ash and cullet) provided by the Census of Manufactures "Materials Consumed by Kind," tables in the 1963, 1967 and 1972 publications (2,6). Product category end-use allocations for pressed, blown and flat glass were derived from the Census of Manufactures and INFORUM input-output model. Similar to the other material history descriptions, Table A-5 shows the historical time series tonnage data and Figure A-4 shows the material flow of glass from the production to consumption stage.

There are relatively few data for the glass beverage containers and other packaging and container end-use markets in the earlier years of the time series. The assumed product lifetimes are less than one year for both product end-uses; and thus, the lack of a complete time series will not affect the results of the study. The relatively few data for product end-use categories with assumed lifetimes of less than one year is apparent in quite a few of the historical time series.

Lead

The data from *Mineral Facts and Problems* (44) and *Lead 1977*(58), two Bureau of Mines publications, were selected as the basis of the material history time series. Estimates were adjusted, however, to specify more product category end-uses. The methodology used to group various lead products listed in the *Minerals Yearbook* (51) into end-uses in the other sources was altered. Batteries tonnage estimates were isolated from the transportation and electrical electronics products end-use category. The source of the time series for batteries was the *Minerals Yearbook*, and the residual tonnage figure, after the adjustment, included the use of lead in bearings and solder, and weights and ballast in wheels and keels, respectively in the transportation category. This residual figure depicting direct use in the transportation category was then allocated between the detailed end-use categories, automobiles and other transportation based on estimates from INFORUM. The residual figure, after adjustment for batteries, also depicts direct use in the electrical and electronics products category where lead is used in cable coveraings, solder, brass and bronze. The ordnance and buildings and structures end-use categories are taken directly from the Bureau of Mines time series. The historical time series is shown in Table A-6 and these estimates include new scrap. The material flow diagram for lead is presented in Figure A-5.

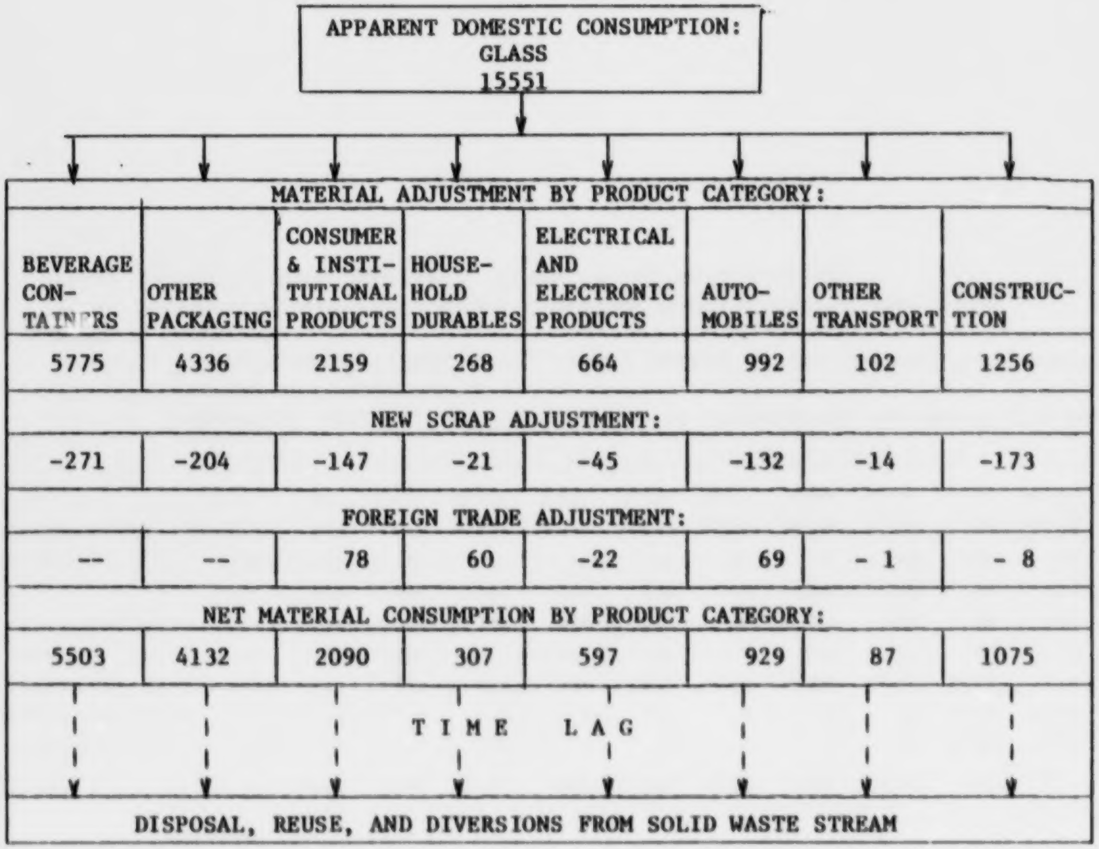
Leather

In the literature search, no published estimates of apparent consumption were found by product end-use. IR&T derived estimates by product end-use, employing ton-per-dollar ratios from the Census of Manufactures (46) and the input-output model's product end-use allocations. A well defined time series does not exist for leather. The estimated historical time series is presented in Table A-7 and the material flow diagram for leather is displayed in Figure A-6.

TABLE A-5. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR GLASS
(Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Beverage Containers	0	0	0	0	0	0	0	0	0	5,761	6,921	6,366
Other Packaging & Containers	0	0	0	0	0	0	0	0	0	4,633	4,370	4,783
Consumer/Institutional Prod,	499	562	625	691	792	893	995	1,097	1,412	1,730	2,054	2,380
Household Durables	91	99	106	113	127	140	151	165	196	231	257	295
Electrical/Electronic Prod.	171	193	215	235	268	301	335	367	463	556	644	732
Automobile	662	675	689	704	744	803	845	906	915	991	910	1,094
Other Transportation	69	70	72	73	78	83	87	93	95	102	94	113
Buildings & Structures	912	930	947	963	1,016	1,050	1,103	1,134	1,133	1,218	1,146	1,385
TOTAL	2,404	2,529	2,654	2,779	3,025	3,270	3,516	3,762	4,214	15,222	16,396	17,148

Source: *Current Industrial Reports, Series M32G, Glass Containers,* Bureau of the Census, U.S. Department of Commerce.
Census of Manufactures (1963, 1967, 1972), Bureau of the Census, U.S. Department of Commerce.
Glass Containers 1973-1974, Glass Container Manufacturer's Institute.
Glass Packaging Institute 1977, Glass Packaging Institute.



APPARENT DOMESTIC CONSUMPTION:
GLASS
15551

MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:							
BEVERAGE CONTAINERS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	HOUSEHOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	AUTOMOBILES	OTHER TRANSPORT	CONSTRUCTION
5775	4336	2159	268	664	992	102	1256
NEW SCRAP ADJUSTMENT:							
-271	-204	-147	-21	-45	-132	-14	-173
FOREIGN TRADE ADJUSTMENT:							
--	--	78	60	-22	69	- 1	- 8
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:							
5503	4132	2090	307	597	929	87	1075

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

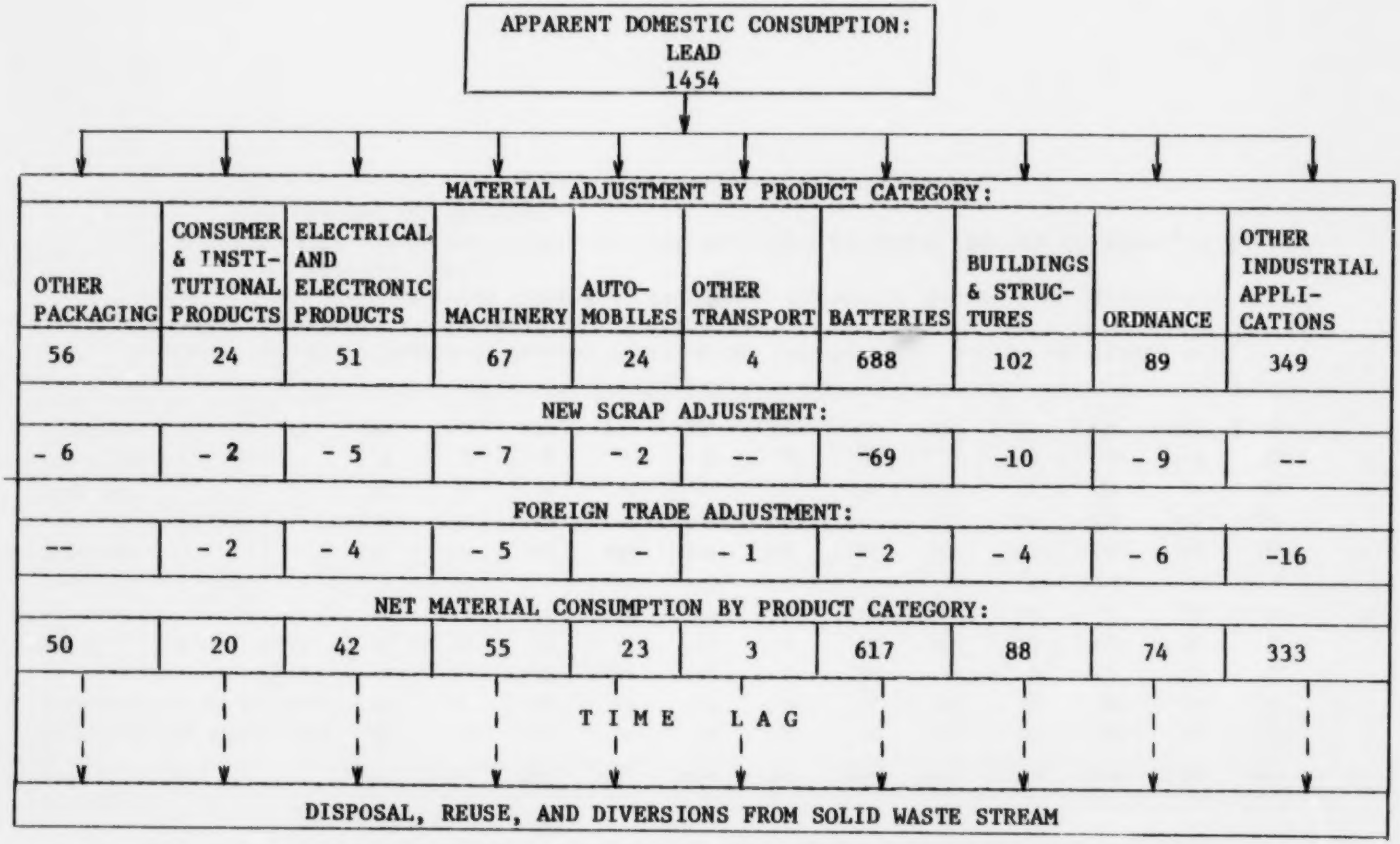
Source: International Research and Technology Corporation.

Figure A-4. Material flow diagram of glass in 1971 (in 10^3 metric tons).

TABLE A-6. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR LEAD (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Other Packaging & Containers	55	52	62	66	69	74	72	65	67	69	65	62
Consumer/Institutional Prod.	26	22	19	18	20	35	36	38	62	49	21	27
Electrical/Electronic Prod.	39	37	39	41	23	21	20	10	9	11	22	56
Machinery/Industrial Equip.	68	59	51	47	55	94	98	104	169	132	57	74
Automobiles	11	12	13	13	11	13	16	16	17	19	21	26
Other Transportation	1	1	2	2	2	2	2	2	3	3	3	4
Batteries	394	410	468	494	478	507	526	521	573	650	661	758
Buildings & Structures	149	151	165	168	164	153	147	134	130	133	135	112
Ordnance	49	51	54	54	62	64	87	88	91	88	81	98
Other Industrial Appl.	0	0	0	0	0	0	0	0	0	0	421	385
TOTAL	792	795	873	903	884	963	1,004	978	1,121	1,154	1,487	1,602

Source: *Minerals Yearbook*, Annual Publication (1960-1974), Bureau of Mines, U.S. Department of Interior.
Lead 1977, Mineral Commodity Profiles, Bureau of Mines, U.S. Department of Interior, 1977.
Mineral Facts and Problems, 1970 and 1975 editions, Bureau of Mines, U.S. Department of Interior.



APPARENT DOMESTIC CONSUMPTION:
LEAD
1454

OTHER PACKAGING	CONSUMER & INSTI-TUTIONAL PRODUCTS	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTO-MOBILES	OTHER TRANSPORT	BATTERIES	BUILDINGS & STRUC-TURES	ORDNANCE	OTHER INDUSTRIAL APPLI-CATIONS
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:									
56	24	51	67	24	4	688	102	89	349
NEW SCRAP ADJUSTMENT:									
- 6	- 2	- 5	- 7	- 2	--	-69	-10	- 9	--
FOREIGN TRADE ADJUSTMENT:									
--	- 2	- 4	- 5	-	- 1	- 2	- 4	- 6	-16
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:									
50	20	42	55	23	3	617	88	74	333

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

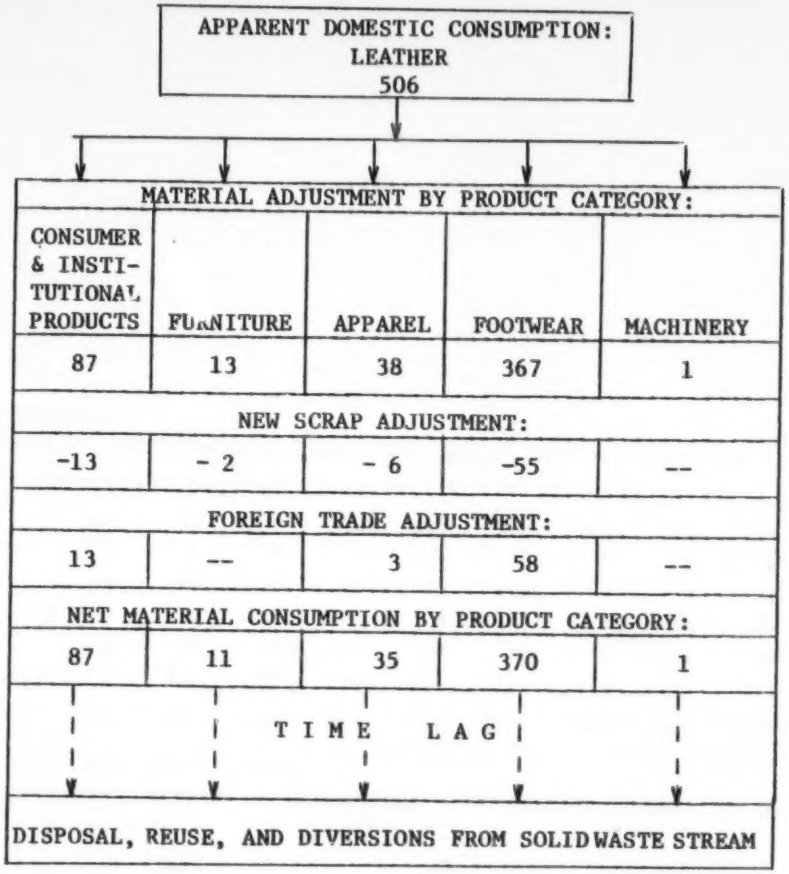
Source: International Research and Technology Corporation.

Figure A-5. Material flow diagram of lead in 1971 (in 10^3 metric tons).

TABLE A-7. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR LEATHER (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Consumer/Institutional Prod.	116	109	109	110	113	117	112	114	113	103	95	97
Furniture & Furnishings	19	18	18	18	19	19	19	19	19	17	16	16
Apparel	51	48	48	48	49	51	49	50	49	45	41	42
Footwear	488	459	460	461	472	489	470	478	473	430	400	405
Machinery/Industrial Equip.	6	6	6	6	6	6	6	6	6	6	5	5
TOTAL	680	640	641	643	659	682	656	667	660	601	557	565

Source: *Census of Manufactures (1967 and 1972)*, Bureau of Census, U.S. Department of Commerce.



APPARENT DOMESTIC CONSUMPTION:
LEATHER
506
TIME LAG
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	APPAREL	FOOTWEAR	MACHINERY
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:	87	13	38	367	1
NEW SCRAP ADJUSTMENT:	-13	- 2	- 6	-55	--
FOREIGN TRADE ADJUSTMENT:	13	--	3	58	--
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	87	11	35	370	1

Source: International Research and Technology Corporation.

Figure A-6. Material flow diagram of leather in 1971 in 10^3 metric tons).

Paper and Paperboard

The Bureau of the Census (59) estimates of apparent consumption in tons was used to establish the material history for paper and paperboard. The American Paper Institute (API) estimates, published in *Statistics of Paper and Paperboard* (60), were also investigated as a possible data source. There is general agreement between the Census and API, although there are variations in data for some years. The data from the Bureau of the Census were chosen since these estimates are more likely to be consistent with the underlying economic data of the input-output model used in this study. Product category allocations were primarily derived from Bureau of the Census data.

Allocations among the product end-use categories are given in Table A-8. If the Census definitions by grade of paper did not coincide with the product categories outlined in this study, other data were employed. These data were obtained primarily from API. In addition, Kline's *Marketing Guide to the Paper and Paperboard Industry* (72) and the Midwest Research Institute's *The Role of Non-Packaging in Solid Waste Management* (23) was also examined. The historical time series production data and material flow diagram for paper and paperboard are presented in Tables A-9 and A-10, and in Figures A-7 and A-8.

Plastics

Total apparent consumption estimates and market end-use data were derived primarily from McGraw-Hill's publication *Modern Plastics* (41). *Modern Plastics* uses control totals published by the Society of the Plastic Industry (SPI) in *Facts and Figures of the Plastics Industry* (62), and then allocates these totals among market end-use categories. A large portion of plastic consumption was omitted by this source and time series data by product category were only available for the years 1967 through 1971. To obtain appropriate estimates by end-use product categories as defined in this study, *Modern Plastics* detailed end-use estimates by resin were used for the consumer and institutional products category (i.e., luggage, medical products, records, optical goods, tools, and recreational products) and machinery and industrial equipment category. Data for the earlier years of the time series were derived from the product end-use estimates and trends in plastic usage published in *Markets for Plastics* (63). These estimates were compared with data published in *Modern Plastics* for the earlier years wherever possible. A miscellaneous category was used for plastics employed in agricultural applications; plastics used in the production of textiles and paints were included in the "other industrial applications" category.

The methodology used to develop data for this material is rather complicated. The data was adjusted to control totals in the historical time series. An investigation of data sources showed that *Modern Plastics* makes the most comprehensive survey of the industry's production figures, and the U.S. International Trade (formerly Tariff) Commission's annual publication *Synthetic Organic Chemicals* (61)

TABLE A-8. PAPER AND PAPERBOARD PRODUCT CATEGORY ALLOCATION ASSUMPTIONS

Material/Product Category	Grade
PAPER:	
Newspaper	Newsprint
Books, Periodicals & Other Printing Paper	Groundwood Coated Printing Book Paper
Writing & Other Fine Paper	Writing Paper Bleached Bristol
Disposable Products	Sanitary Paper
Other Packaging & Containers	Tissue Paper Unbleached Kraft Packaging Packaging & Industrial Converting
Consumer & Institutional Products	Special Industrial (other grades)
Electrical & Electronic Products	Special Industrial (electrical & cable paper)
PAPERBOARD:	
Books, Periodicals & Other Printing Paper	Wet Machine Board (according to Kline's *Marketing Guide*)
Other Packaging Containers	Corrugated Paper Non-Corrugated Liner Board Bleached Packaging & Converting (according to API) Combination Board-Bending Special Combination (fiber cans, drums, tubes & boards)
Consumer & Institutional Products	Special Combination (Other) Bleached Packaging & Converting (according to API) Wet Machine Board (according to Kline's *Marketing Guide*)
Footwear	Wet Machine Board (shoeboard)
Electrical & Electronic Products	Wet Machine Board (according to Kline's *Marketing Guide*)
Automobiles	Special Combination (panelboard) Wet Machine Board (according to Kline's *Marketing Guide*)
Buildings & Structures	Construction Paper Construction Board

Source: James Rauch. *Kline Guide to the Paper and Pulp Industry, 3rd Edition*, Charles H. Kline & Company, Fairfield, New Jersey, 1976.

TABLE A-9. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR PAPER (Thousand Short Tons)

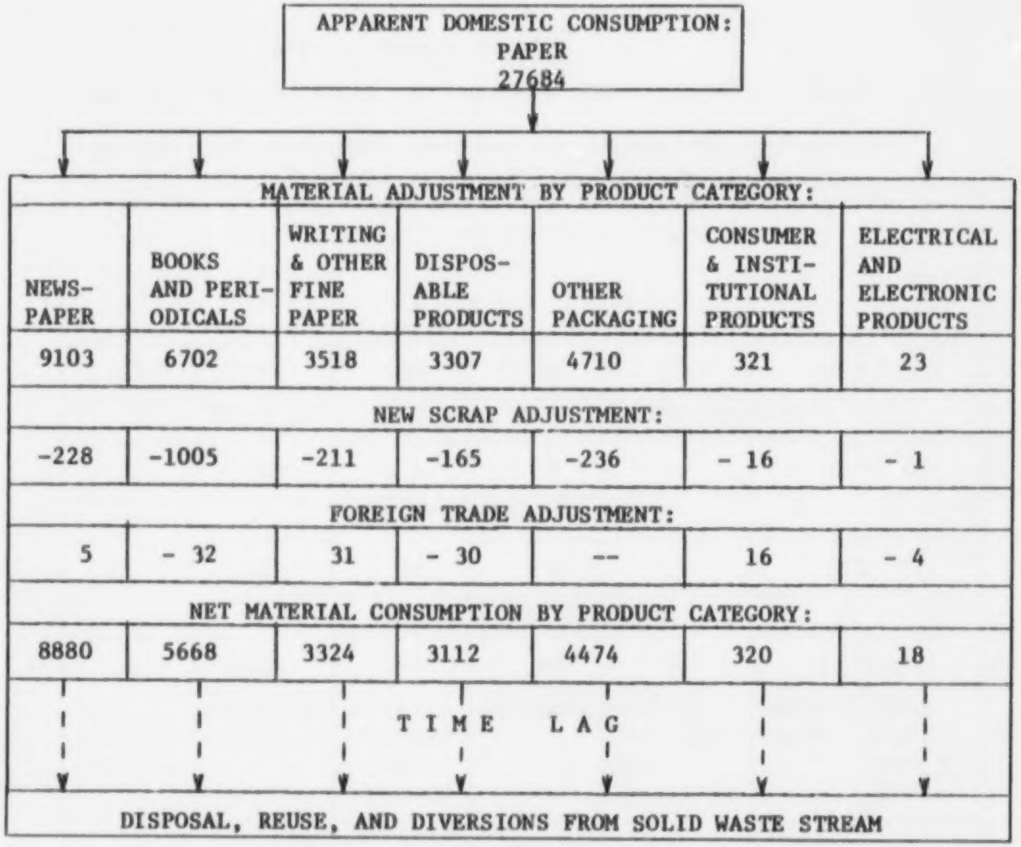
Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Newspaper	0	7,336	7,473	7,508	8,086	8,419	9,238	9,108	9,289	9,915	9,836	10,036
Books, Periodicals & Other	0	4,695	4,938	5,244	5,600	6,023	6,710	6,662	7,007	7,376	7,353	7,389
Writing & Other Fine Paper	0	0	0	0	2,827	3,132	3,437	3,459	3,689	3,967	3,859	3,880
Disposable Products	0	0	2,174	2,335	2,498	2,632	2,835	2,943	3,141	3,324	3,531	3,646
Other Packaging & Containers	0	0	0	0	0	0	0	0	0	5,231	5,160	5,193
Consumer/Institutional Prod.	200	235	231	228	252	266	294	298	336	356	338	358
Electrical/Electronic Prod.	33	36	35	34	37	38	38	34	34	33	33	28
TOTAL	233	12,302	14,851	15,349	19,300	20,510	22,552	22,504	23,496	30,202	30,110	30,530

Source: *Statistics of Paper and Paperboard, 1976*, American Paper Institute.
Current Industrial Reports, Series M26A, Pulp, Paper and Board, Bureau of the Census, U.S. Department of Commerce.

TABLE A-10. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR PAPERBOARD (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Books, Periodicals	53	54	58	55	59	59	65	59	53	50	48	46
Other Packaging & Containers	0	0	0	0	0	0	0	0	0	22,633	22,140	22,311
Consumer/Institutional Prod.	0	607	579	631	685	708	667	466	565	511	355	383
Footwear	59	59	61	58	61	60	59	52	49	46	44	44
Electrical/Electronic Prod.	22	17	19	11	13	11	10	11	20	20	19	20
Automobiles	46	42	41	39	53	60	54	53	60	53	51	57
Buildings & Structures	0	4,008	4,256	4,506	4,796	4,933	4,637	4,640	5,277	5,499	5,279	6,227
TOTAL	180	4,787	5,014	5,300	5,667	5,831	5,492	5,281	6,024	28,812	27,936	29,088

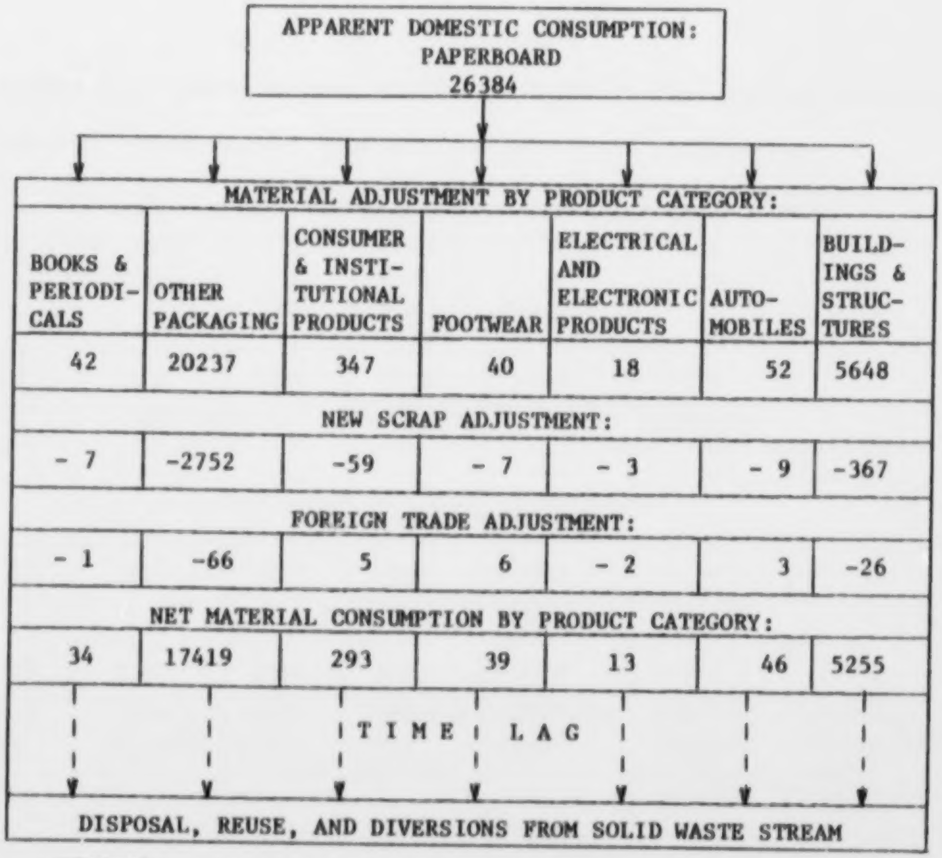
Source: *Statistics of Paper and Paperboard, 1976*, American Paper Institute.
Current Industrial Reports, Series M26A, Pulp, Paper and Board, Bureau of the Census, U.S. Department of Commerce.



MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:						
NEWS-PAPER	BOOKS AND PERIODICALS	WRITING & OTHER FINE PAPER	DISPOS-ABLE PRODUCTS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	ELECTRICAL AND ELECTRONIC PRODUCTS
9103	6702	3518	3307	4710	321	23
NEW SCRAP ADJUSTMENT:						
-228	-1005	-211	-165	-236	- 16	- 1
FOREIGN TRADE ADJUSTMENT:						
5	- 32	31	- 30	--	16	- 4
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:						
8880	5668	3324	3112	4474	320	18
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM						

Source: International Research and Technology Corporation.

Figure A-7. Material flow diagram of paper in 1971 (in 10^3 metric tons).


APPARENT DOMESTIC CONSUMPTION:
PAPERBOARD
26384
TIME LAG
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

BOOKS & PERIODICALS	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FOOTWEAR	ELECTRICAL AND ELECTRONIC PRODUCTS	AUTOMOBILES	BUILDINGS & STRUCTURES
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:						
42	20237	347	40	18	52	5648
NEW SCRAP ADJUSTMENT:						
- 7	-2752	-59	- 7	- 3	- 9	-367
FOREIGN TRADE ADJUSTMENT:						
- 1	-66	5	6	- 2	3	-26
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:						
34	17419	293	39	13	46	5255

Source: International Research and Technology Corporation.

Figure A-8. Material flow diagram of paperboard in 1971 (in 10^3 metric tons).

includes some plastic categories while excluding others, making their estimates less reliable. (A comparison of *Modern Plastics*, SPI, and the U.S. Tariff Comission's plastic sales data is given in Table A-11). It was also noted that although there are differences between the IR&T and Franklin plastic estimates for EPA's Office of Solid Waste, Franklin also employs *Modern Plastics* figures in his methodology. In addition, the original source of A.D. Little's estimates in *Incentives for Recycling and Reuse of Plastics* (64), which was used in the Franklin analysis, was the *Modern Plastics* data. Thus, the *Modern Plastics* data used in this study provide reliable and comprehensive time series data. Data from 1972 to 1976 were included in the analysis, especially plastics packaging data, because usage has changed considerably in more recent years. The historical time series production data is presented in Table A-12 and the flow of plastics for 1971 from production to consumption is presented in Figure A-9.

Table A-12 provides the breakdown of plastics by product end-use category for 1960-1971. It should be noted that, due to the recent trend of substituting plastics for glass or metal beverage containers, 1971 is the first year that beverage containers are included as an end-use category. Changes to material flows are included as inputs for the later years, 1972-1976. The fact that beverage containers have an assumed product lifetime of less than one year means that the lack of a complete time series will not greatly affect the reliability of forecasts of tonnage figures. In addition, the other industrial applications category and miscellaneous category have fairly short time series from 1967 to 1971 due to the fact that residuals of plastic tonnage have only been identifiable in recent years when the product category end-use data were more detailed.

Rubber

The Rubber Manufacturers Asscociation's publication (65) is the only available source of apparent domestic consumption data. The data in this publication are divided into tire and non-tire products and the rubber had to be allocated among the non-tire market end-uses according to the IR&T descriptions of product category market end-uses. *Rubber Age* (66) has published estimates of rubber use for footwear, mechanical goods, wire and cable, latex foam products, and others but there is no breakdown in tonnage available for market end-use categories in this study. Consequently, estimates were derived from the Census of Manufactures (46) data for the Fabricated Rubber Products SIC 3069.

The historical time series tonnage data are presented in Table A-13 and the flow of rubber from production to consumption is represented in Figure A-10.

Textiles

The Textile Economics Bureau publication *Textile Organon* (67) is the primary source of the total annual consumption figures for textiles.

TABLE A-11. COMPARISON OF PLASTICS SALES DATA FOR 1972 (in 10^6 lbs.)

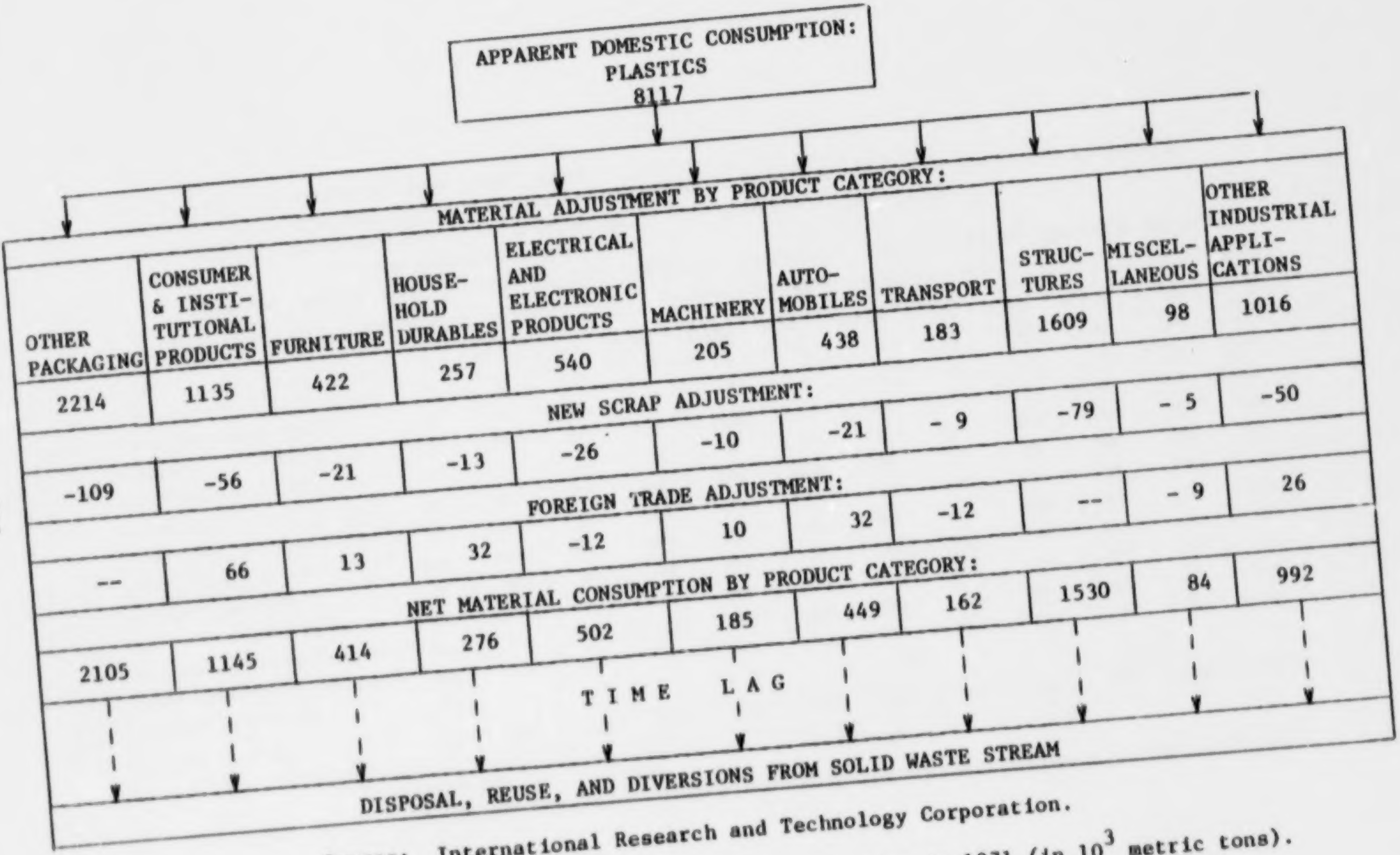
Material	*Modern Plastics*	Society of the Plastics Industry	U.S. Tariff Commission
Acrylic	459	NA	627
Cellulosics	165	NA	252
Epoxy	183	183	179
Nylon	148	151	119
Phenolic	1435	1431	1227
Polyester	917	906	889
HDPE	2342	2387	2054
LDPE	5230	5263	4877
Polyacetal	58	NC	NC
Polycarbonate	56	NC	NC
Polypropylene	1689	1705	1685
Polystyrene & co-polymers	4654	4049	4557
Polystyrene	3429	3162	3646
ABS	787	785	810
SAN	101	102	101
Other	337		
Polyvinyl Chloride & co-polymers	4355	4354	4435
Urea & Melamine	906	897	780
Urethane Foam	1088	1190	NC
Other			
GRAND TOTAL	23685	22516	21681
Exports	664	663	663

Source: *Modern Plastics*, McGraw-Hill Publication.
Facts and Figures of the Plastics Industry: 1977 Edition,
Society of the Plastics Industry, September 1977.
Synthetic Organic Chemicals, U.S. International Trade Commission.

TABLE A-12. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR PLASTICS (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Beverage Containers	0	0	0	0	0	0	0	0	0	0	0	20
Other Packaging & Containers	300	500	650	750	900	977	1,100	1,300	1,507	1,893	2,298	2,450
Consumer/Institutional Prod.	309	350	428	468	513	563	668	773	904	1,080	1,134	1,259
Furniture & Furnishings	200	205	215	250	260	290	350	344	306	398	394	467
Household Durables	90	92	93	98	115	150	190	198	234	267	285	285
Electrical/Electronic Prod.	235	246	260	283	311	339	368	396	488	580	617	599
Machinery/Industrial Equip.	53	63	78	93	110	130	148	155	178	196	230	230
Automobiles	59	93	124	150	183	215	246	282	301	426	462	483
Other Transportation	41	45	51	58	65	70	125	144	172	228	197	206
Buildings & Structures	403	460	546	632	718	832	975	1,065	1,149	1,284	1,478	1,775
Other Industrial Appl.	0	0	0	0	0	0	0	0	0	0	1,184	1,124
Miscellaneous	0	0	0	0	0	0	0	75	85	95	99	110
TOTAL	1,690	2,054	2,445	2,782	3,175	3,566	4,170	4,732	5,324	6,447	8,378	9,008

Source: *Facts and Figures of the Plastics Industry: 1977 edition*, Society of the Plastics Industry, New York.
Modern Plastics, McGraw-Hill publications, New York.
Markets for Plastics, D.V. Rosato, W.,. Fallon, Van Nostrand Reinhold Company, New York, 1969.



APPARENT DOMESTIC CONSUMPTION:
PLASTICS
8117

	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	HOUSEHOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTOMOBILES	TRANSPORT	STRUCTURES	MISCELLANEOUS	OTHER INDUSTRIAL APPLICATIONS
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:	2214	1135	422	257	540	205	438	183	1609	98	1016
NEW SCRAP ADJUSTMENT:	-109	-56	-21	-13	-26	-10	-21	- 9	-79	- 5	-50
FOREIGN TRADE ADJUSTMENT:	--	66	13	32	-12	10	32	-12	--	- 9	26
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	2105	1145	414	276	502	185	449	162	1530	84	992

T I M E L A G

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

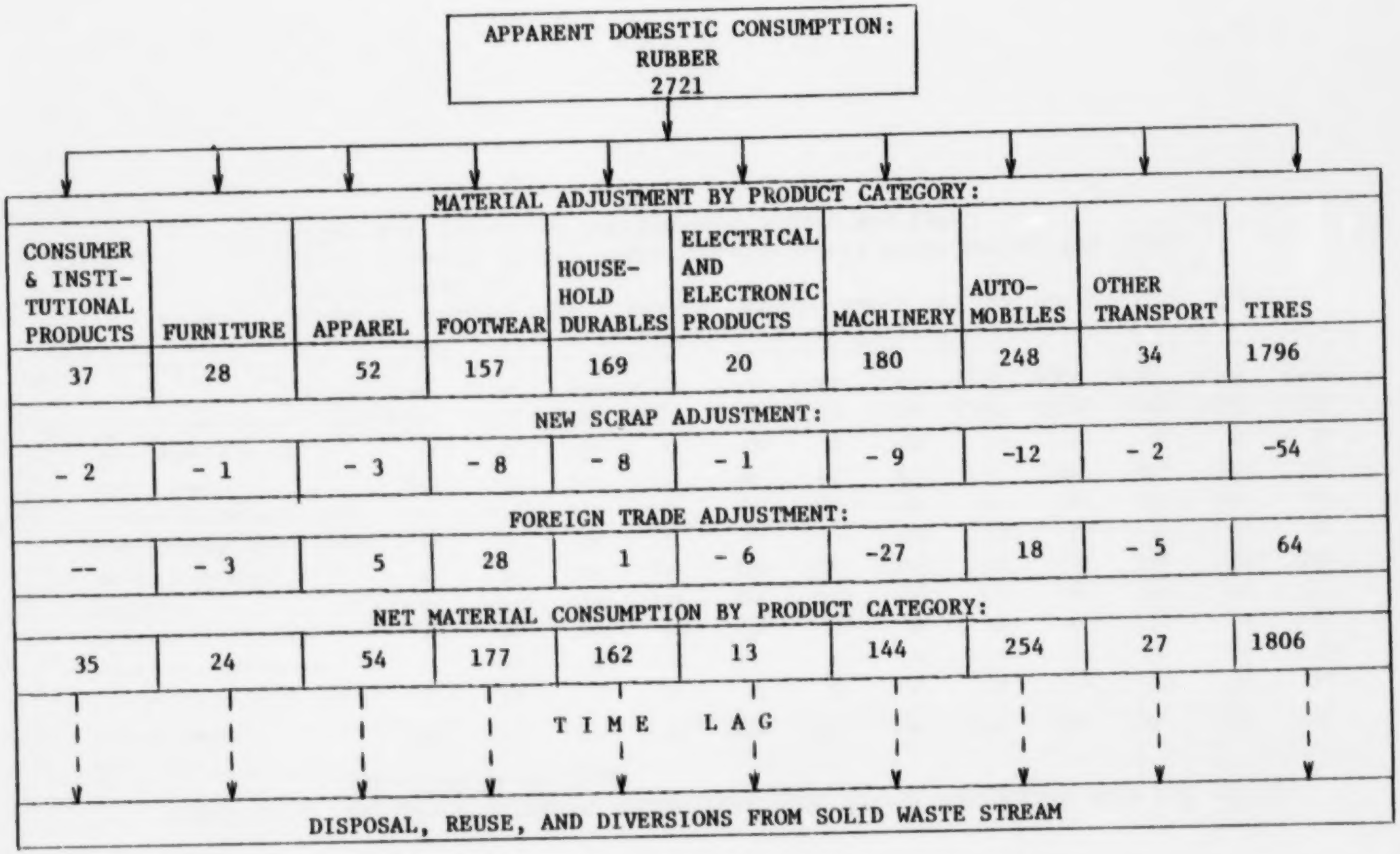
Source: International Research and Technology Corporation.

Figure A-9. Material flow diagram of plastics in 1971 (in 10^3 metric tons).

TABLE A-13. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR RUBBER (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Consumer/Institutional Prod.	25	25	29	31	33	35	36	36	39	39	41	41
Furniture & Furnishings	19	20	22	23	24	24	27	26	29	29	30	31
Apparel	57	58	66	69	75	76	81	80	89	79	77	57
Footwear	107	109	124	130	140	143	152	151	166	169	171	173
Household Durables	90	90	104	109	118	120	128	126	138	160	160	186
Electrical/Electronic Prod.	14	14	16	17	17	18	19	19	20	21	21	22
Machinery/Industrial Equip.	157	159	179	187	202	205	221	217	239	231	227	199
Automobiles	143	145	166	175	188	191	203	202	224	246	246	273
Other Transportation	21	21	24	24	26	27	29	29	32	34	34	38
Tires & Inner Tubes	1,114	1,073	1,195	1,211	1,342	1,463	1,581	1,485	1,799	1,929	1,767	1,980
TOTAL	1,747	1,714	1,925	1,976	2,165	2,302	2,477	2,371	2,775	2,937	2,774	3,000

Source: *Census of Manufactures (1967 and 1972)*, Bureau of the Census, U.S. Department of Commerce.
Rubber Industry Facts, Rubber Manufacturers Association, New York.
Rubber Age, Palmerton Publishing Company, New York.



APPARENT DOMESTIC CONSUMPTION:
RUBBER
2721

CONSUMER & INSTI-TUTIONAL PRODUCTS	FURNITURE	APPAREL	FOOTWEAR	HOUSE-HOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTO-MOBILES	OTHER TRANSPORT	TIRES
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:									
37	28	52	157	169	20	180	248	34	1796
NEW SCRAP ADJUSTMENT:									
- 2	- 1	- 3	- 8	- 8	- 1	- 9	-12	- 2	-54
FOREIGN TRADE ADJUSTMENT:									
--	- 3	5	28	1	- 6	-27	18	- 5	64
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:									
35	24	54	177	162	13	144	254	27	1806

Source: International Research and Technology Corporation.

Figure A-10. Material flow diagram of rubber in 1971 (in 10^3 metric tons).

Man-Made Fibers Source Book (73) was also examined to confirm man-made fibers data. *Textile Organon* specifies many market end-uses for textiles which were aggregated into eleven product categories according to the market end-uses in the IR&T model. These categories are apparel, footwear, furniture and furnishings, automobiles, other transportation, electrical and electronic products, tires and inner tubes, consumer and institutional products, machinery and industrial equipment, other industrial applications, and disposables.

The apparel end-use category includes sheer hosiery, anklets and socks, sweaters and related accessories, craft and handwork yarns, underwear and nightwear, robes and loungewear, pile fabrics, lining-type fabrics, apparel lace, retail piece goods, narrow woven apparel, and other apparel and accessories (e.g., handkerchiefs, ties, mittens, and scarves.) Shoes and slippers comprise the footwear end-use category. Manmade fibers and cottons used in boots, tennis shoes, and mesh tops for summer shoes are accounted for in this end-use category.

The furniture and furnishings category includes manmade fibers, cotton and wool used in bedspreads, quilts, blankets, and blanketing, sheets, and other bedding. The category also includes carpets, rugs, face yarn, backing, curtains, drapery and upholstery, and miscellaneous articles, (e.g., woven and lace napery, tablecloths, doilies, shower curtains, and embroidered goods).

The transportation end-use category includes auto seat upholstery, slipcovers, sidewall, headlining and sheeting. Knit and woven fabric used as backing for vinyl sheeting, convertible automobile tops are included in the end-use as well as upholstery used in different modes of transportation (e.g., railroad cars, airplanes, subways, and buses.) The INFORUM model was used to segregate automobile and other transportation for textiles.

The electric applications end-use category includes electric wire insulation and covering of all kinds plus friction tape and cable wrap, stuffing and identification.

The tires end-use category includes all types of tires (e.g., automobile, truck, tractor, off-road, and bicycle), tire cord and tire cord fabric, chafer and other tire components (e.g., flipper fabric, breaker strips, and bead wraps).

The consumer and institutional products end-use category includes medical, surgical and sanitary goods (e.g., bandages, gauzes, adhesive tapes and plasters, cotton diapers, surgical gowns and packs, and non-woven wiping cloths). The end-use category also includes felts, sewing threads, rope, cordage, fishline, bags, sports equipment and hand umbrellas, manmade stuffing and filling materials. The machinery and industrial equipment end-use category includes hoses (fire, chemical and fuel), belting (e.g., conveyor belts) transmission belts and V-belts.

The other industrial applications end-use category includes reinforced plastics, paper and tape reinforcing, and non-woven bonded structures for paper and tape reinforcing.

The disposable end-use category includes textiles used for filtration. This includes woven and non-woven fibers for wet and dry filtration, including tea bags.

The material time series data for textiles are presented in Table A-14. It should be noted that for a few product category end-uses, such as other industrial applications, tires, footwear, and disposables, the time series data are relatively limited. The fewer number of available estimates for these end-uses will not affect the forecasts because the product lifetime assumptions for these end-uses are relatively short. A material flow diagram is presented for textiles in Figure A-11.

Wood

Apparent domestic consumption data for wood is provided by two sources, *The Demand and Price Situation for Forest Products* (Table 5) (68) and *The Outlook for Timber in the United States* (42). Product category allocations were derived from *The Outlook for Timber in the United States* where data on buildings and structures are presented in Table 136, p. 181, data on furniture, consumer products and machinery in Table 128, p. 169; and data on other transportation data on p. 166. It was not possible to obtain the most recent data from the Forest Service because the update of survey data will take place later this year. The historical time series data are presented in Table A-15 and the flow of wood in 1971 from production to consumption is depicted in Figure A-12.

Zinc

Similar to the other nonferrous metals, the time series for zinc estimates was taken from Bureau of Mines *Mineral Facts and Problems* (44) and Mineral Commodity Profiles *Zinc 1977* (69). The source of the brass and bronze end-use data in the government publications is the Copper Development Association's annual publication *Annual Data 1976: Copper Supply and Consumption, 1956-1975* (50), and the source of data for the use of zinc in galvanizing is the American Iron and Steel Institute's *Annual Report* (38, 39). Based on the definitions of the categories in the *Mineral Facts and Problems*, the use of zinc was allocated to seven product categories; buildings and structures, household durables, electrical and electronic products, automobiles, other transportation, machinery, and consumer and institutional products.

The Bureau of Mines definition of electrical and electronic products included the use of zinc in household durables. According to the electrical and electronic end-use description, zinc is mainly employed in the manufacture of household cooking equipment, household refrigerators and freezers, household laundry equipment, electric housewares and fans, household vacuum cleaners, sewing machines, and

TABLE A-14. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR TEXTILES (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Disposables	0	0	0	0	0	0	0	0	0	0	12	13
Consumer/Institutional Prod.	330	326	343	346	382	424	478	472	523	530	481	522
Furniture & Furnishings	834	851	945	1,024	1,133	1,243	1,289	1,308	1,478	1,521	1,476	1,670
Apparel	1,628	1,662	1,764	1,820	1,900	1,978	2,021	2,042	2,197	2,140	2,174	2,344
Footwear	0	0	0	0	0	0	0	0	29	30	32	33
Electrical/Electronic Prod.	8	8	8	9	9	10	10	11	11	12	12	13
Machinery/Industr-al Equip.	27	29	31	33	35	37	38	39	40	41	42	45
Automobiles	17	18	19	19	21	23	25	24	25	27	26	26
Other Transportation	14	15	15	15	17	19	20	20	21	22	22	22
Tires & Inner Tubes	0	0	0	0	0	0	0	285	291	295	286	312
Other Industrial Appl.	0	0	0	0	0	0	0	0	0	0	171	185
TOTAL	2,850	2,909	3,125	3,266	3,497	3,734	3,881	4,201	4,615	4,618	4,722	5,185

Source: *Textile Organon*, Annual November Issue, Textile Economics Bureau, Inc., New York. *Man-Made Fibers Source Book*, Man-Made Fibers Producers Association, Inc., 1978.

APPARENT DOMESTIC CONSUMPTION:
TEXTILES
4704

FURNITURE AND FURNISHINGS	CONSUMER & INSTITUTIONAL PRODUCTS	FOOTWEAR	APPAREL	MACHINERY	ELECTRICAL AND ELECTRONIC PRODUCTS	TIRES	AUTOMOBILES	OTHER TRANSPORT	DISPOSABLE PRODUCTS	OTHER INDUSTRIAL APPLICATIONS
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:										
1515	473	30	2126	41	12	283	24	20	12	168
NEW SCRAP ADJUSTMENT:										
-76	-24	- 2	-213	- 2	- 1	-14	- 1	- 1	- 1	- 8
FOREIGN TRADE ADJUSTMENT:										
-24	4	6	179	- 5	- 4	9	1	- 8	--	3
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:										
1463	453	34	2092	34	7	278	24	11	11	163

TIME LAG

DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

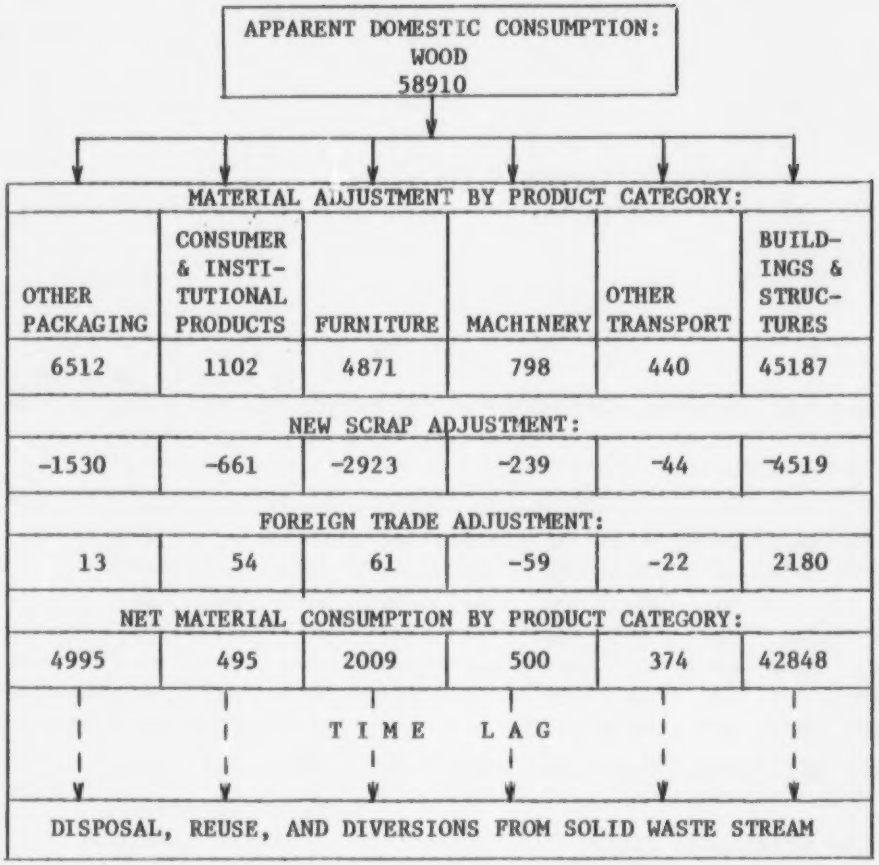
Source: International Research and Technology Corporation.

Figure A-11. Material flow diagram of textiles in 1971 (in 10^3 metric tons).

TABLE A-15. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR WOOD
(Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Other Packaging & Containers	5,400	5,250	5,450	5,600	5,800	5,770	6,300	5,950	6,650	6,600	6,620	7,180
Consumer/Institutional Prod.	1,247	1,215	1,247	1,255	1,215	891	891	891	1,012	1,093	1,150	1,215
Furniture & Furnishings	3,600	3,640	3,830	3,900	4,100	4,410	4,500	4,400	4,700	4,800	4,810	5,370
Machinery/Industrial Equip.	530	550	620	650	700	800	800	800	800	800	810	880
Other Transportation	453	445	468	485	485	424	409	399	438	477	470	485
Buildings & Structures	35,350	35,400	38,025	40,810	43,500	44,650	44,600	42,760	46,300	46,130	44,970	49,820
TOTAL	46,580	46,500	49,640	52,700	55,800	56,945	57,500	55,200	59,900	59,900	58,830	64,950

Source: *The Demand and Price Situation for Forest Products, 1973-1974*, U.S. Department of Agriculture, Forest Service, September 1974.
Outlook for Timber in the United States, U.S. Department of Agriculture, Forest Service, October 1973.


APPARENT DOMESTIC CONSUMPTION:
WOOD
58910
T I M E   L A G
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

	OTHER PACKAGING	CONSUMER & INSTITUTIONAL PRODUCTS	FURNITURE	MACHINERY	OTHER TRANSPORT	BUILDINGS & STRUCTURES
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:	6512	1102	4871	798	440	45187
NEW SCRAP ADJUSTMENT:	-1530	-661	-2923	-239	-44	-4519
FOREIGN TRADE ADJUSTMENT:	13	54	61	-59	-22	2180
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:	4995	495	2009	500	374	42848

Source: International Research and Technology Corporation.

Figure A-12. Material flow diagram of wood in 1971 (in 10^3 metric tons).

other household applicances. Zinc is also used in electric transmission equipment, pumps, mechanical transmission, and control rods. The total figure specified in the *Minerals Facts and Problems* was allocated between the two end-use categories, household durables and electrical and electronic products based on economic data in the INFORUM model.

The consumer and institutional products end-use category includes the use of zinc (brass) in costume jewelry, statuary and decorative applications, zippers, instrument bezels, and gasoline lawnmowers.

The Bureau of Mines transportation end-use includes zinc used in motor vehicles and equipment, such as passenger car, truck and bus bodies and motor vehicle parts (carburetors, grilles and trim) and accessories. This product category also includes aircraft and parts (engines, propellers, and equipment), ship and boat building, railroad and miscellaneous modes of transportation, (e.g., motorcycles, bicycles and trailer coaches.) The INFORUM model was used to allocate the general product category data to automobile end-use and other transportation end-use product categories.

The other Bureau of Mines product categories, buildings and structures, and machinery, included the use of zinc in product end-use markets that were consistent with the IR&T model categories. Thus, the data for these end-uses were taken directly from the source. In the buildings and structures end-use category, zinc is used in metal sanitary ware, plumbing, fitting and brass goods, and heating equipment. Zinc is also used in fabricated structural steel, sash and trim on metal doors, fabricated platework, and architectural and miscellaneous metal work. In galvanizing, zinc is used to protect steel beams, girders, and fasteners, such as nuts and bolts to protect steel roofing and siding.

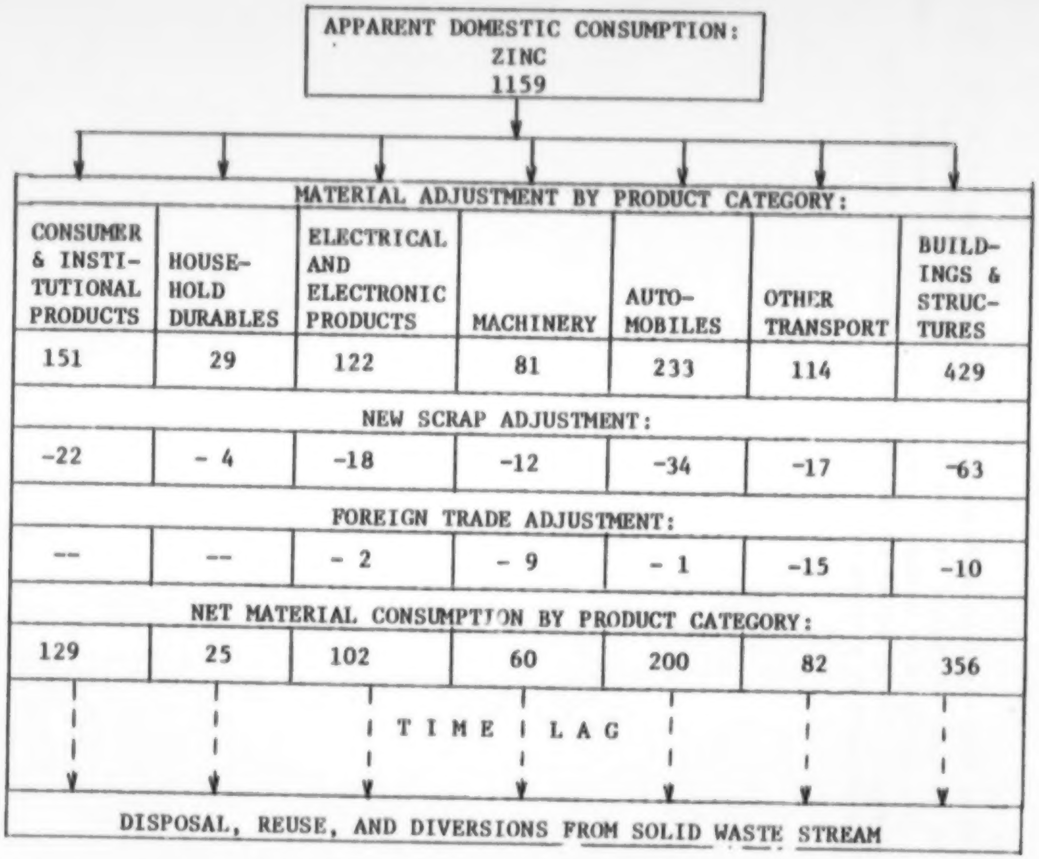
The machinery end-use category includes the use of zinc in engines, turbines and farm machinery, construction, mining and metal working machinery, and office, computing, and accounting machines. Zinc is also used in brass bearings, bushings and tubing, galvanized sheet, fittings, fasteners, diecast parts, and fixtures.

The historical time series data by product category are presented in Table A-16; the adjusted data include new scrap. The zinc material flow diagram for 1971 is displayed in Figure A-13.

TABLE A-16. REFERENCE SCENARIO. HISTORICAL TIME SERIES PRODUCTION DATA FOR ZINC (Thousand Short Tons)

Product Category	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Consumer/Institutional Prod.	122	130	167	144	144	176	250	239	250	253	228	166
Household Durables	25	26	34	29	29	36	47	45	47	47	37	32
Electrical/Electronic Prod.	108	115	149	127	129	156	203	194	203	204	162	134
Machinery/Industrial Equip.	99	107	138	118	120	144	141	127	133	126	107	89
Automobiles	94	182	235	211	213	258	284	245	257	306	224	257
Other Transportation	45	89	116	104	105	127	140	122	127	150	110	126
Buildings & Structures	365	388	503	446	450	547	504	438	458	488	469	473
TOTAL	858	1,037	1,342	1,179	1,190	1,444	1,569	1,410	1,475	1,574	1,337	1,277

Source: *Zinc*, Mineral Commodity Profiles, Bureau of Mines, U.S. Department of Interior.
Mineral Facts and Problems, 1970 and 1975 editions, Bureau of Mines, U.S. Department of Interior.
Annual Data 1976: Copper Supply and Consumption 1956-1975, Copper Development Association.
Annual Statistical Report, 1976, American Iron and Steel Institute.


APPARENT DOMESTIC CONSUMPTION:
ZINC
1159

CONSUMER & INSTITUTIONAL PRODUCTS	HOUSEHOLD DURABLES	ELECTRICAL AND ELECTRONIC PRODUCTS	MACHINERY	AUTOMOBILES	OTHER TRANSPORT	BUILDINGS & STRUCTURES
MATERIAL ADJUSTMENT BY PRODUCT CATEGORY:						
151	29	122	81	233	114	429
NEW SCRAP ADJUSTMENT:						
-22	- 4	-18	-12	-34	-17	-63
FOREIGN TRADE ADJUSTMENT:						
--	--	- 2	- 9	- 1	-15	-10
NET MATERIAL CONSUMPTION BY PRODUCT CATEGORY:						
129	25	102	60	200	82	356

TIME LAG
DISPOSAL, REUSE, AND DIVERSIONS FROM SOLID WASTE STREAM

Source: International Research and Technology Corporation.

Figure A-13. Material flow diagram of zinc in 1971 (in 10^3 metric tons).

MATERIAL FLOWS SELECTED FOR THIS STUDY

The methodology used in this study is based to a large extent on the selection of "path-products" or "chains" to represent the material flows through the economy. The chains are selected for the so-called fourteen categories of "finished materials," that is those materials which do not become embodied in other materials. Because of the numerous number of "chains" in a large input-output table, it was necessary to select only those major chains that represent material flows through the successive stages of production and consumption. The selection procedure for this study has theoretical foundations in the previous IR&T study on household waste.*

The following Figures A-14 through A-27 show the chains selected for each material by product category end-use for inclusion in the material flow analysis. The particular economic sectors specified by taxonomic codes are included in each flow in order to thoroughly explain the methodology used in the chain selection procedure.

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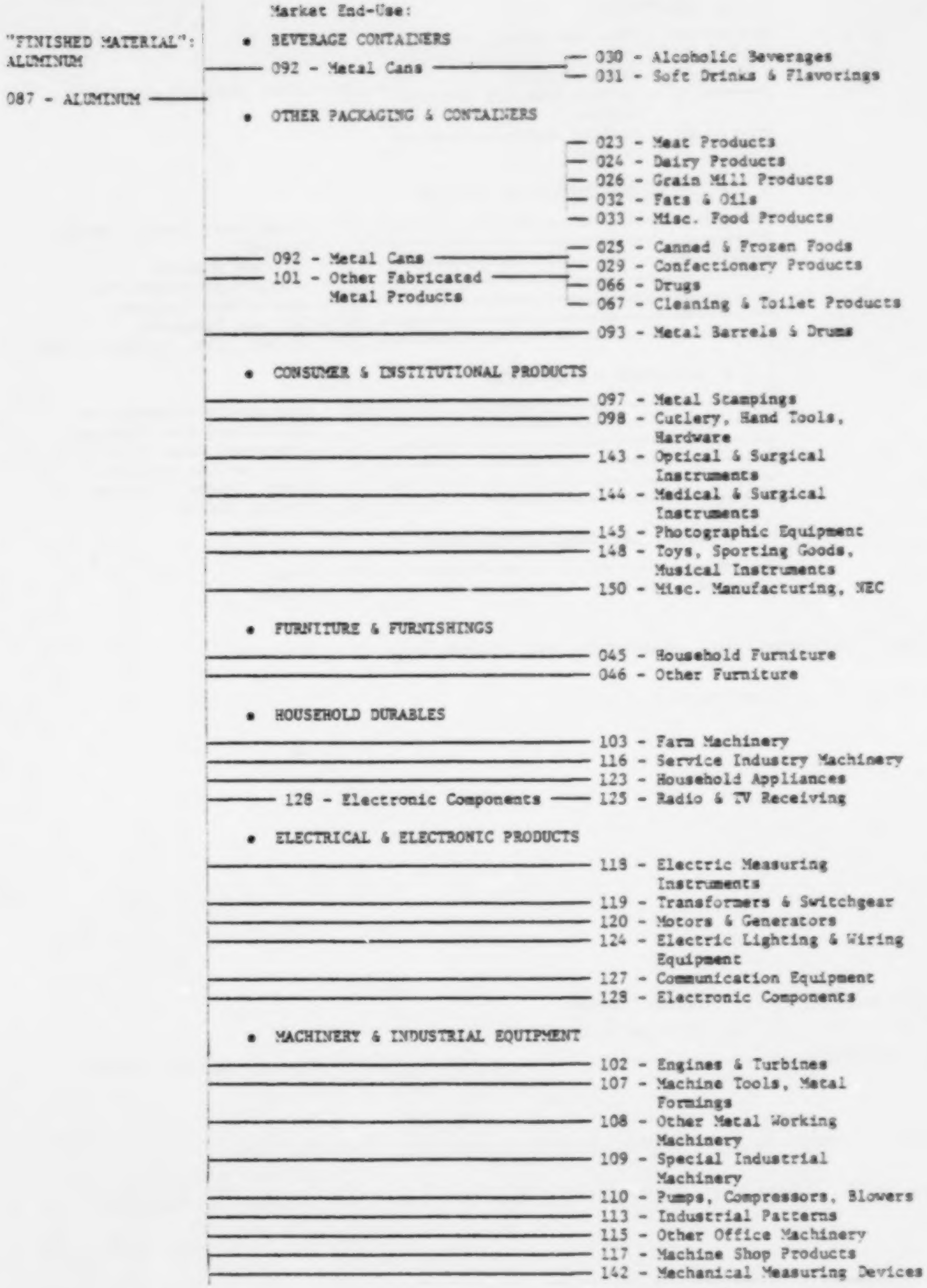
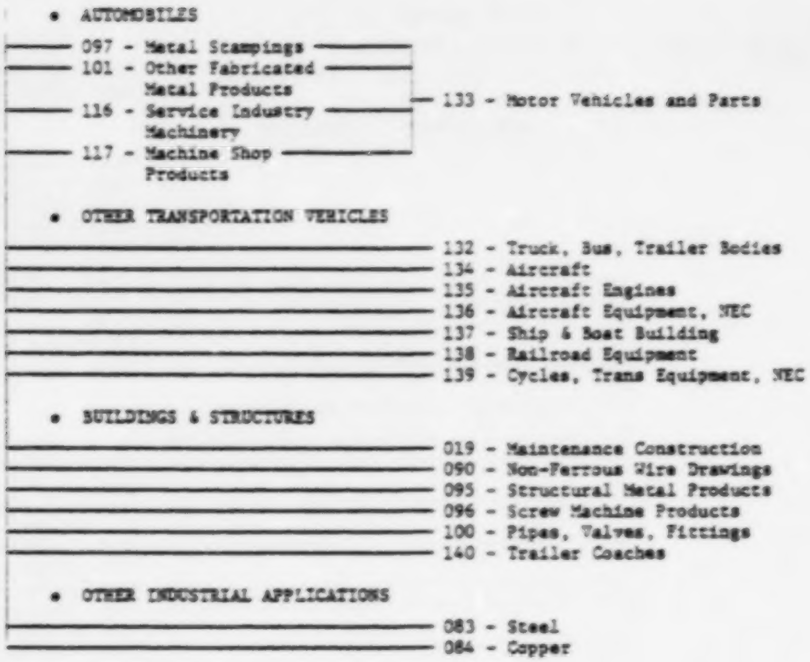
* *Forecasting the Composition and Weights of Household Solid Wastes Using Input-Output Techniques*, IR&T 372-R, November 1975.


Market End-Use:
"FINISHED MATERIAL": ALUMINUM
087 - ALUMINUM
• BEVERAGE CONTAINERS
092 - Metal Cans
030 - Alcoholic Beverages
031 - Soft Drinks & Flavorings
• OTHER PACKAGING & CONTAINERS
023 - Meat Products
024 - Dairy Products
026 - Grain Mill Products
032 - Fats & Oils
033 - Misc. Food Products
092 - Metal Cans
101 - Other Fabricated Metal Products
025 - Canned & Frozen Foods
029 - Confectionery Products
066 - Drugs
067 - Cleaning & Toilet Products
093 - Metal Barrels & Drums
• CONSUMER & INSTITUTIONAL PRODUCTS
097 - Metal Stampings
098 - Cutlery, Hand Tools, Hardware
143 - Optical & Surgical Instruments
144 - Medical & Surgical Instruments
145 - Photographic Equipment
148 - Toys, Sporting Goods, Musical Instruments
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
045 - Household Furniture
046 - Other Furniture
• HOUSEHOLD DURABLES
103 - Farm Machinery
116 - Service Industry Machinery
123 - Household Appliances
128 - Electronic Components
125 - Radio & TV Receiving
• ELECTRICAL & ELECTRONIC PRODUCTS
118 - Electric Measuring Instruments
119 - Transformers & Switchgear
120 - Motors & Generators
124 - Electric Lighting & Wiring Equipment
127 - Communication Equipment
128 - Electronic Components
• MACHINERY & INDUSTRIAL EQUIPMENT
102 - Engines & Turbines
107 - Machine Tools, Metal Formings
108 - Other Metal Working Machinery
109 - Special Industrial Machinery
110 - Pumps, Compressors, Blowers
113 - Industrial Patterns
115 - Other Office Machinery
117 - Machine Shop Products
142 - Mechanical Measuring Devices

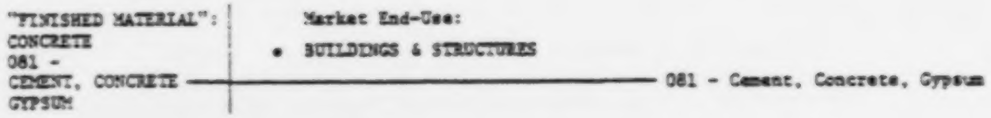
(continued)

Figure A-14. Material flow paths selected for this study: aluminum.


• AUTOMOBILES
097 - Metal Stampings
101 - Other Fabricated Metal Products
116 - Service Industry Machinery
117 - Machine Shop Products
133 - Motor Vehicles and Parts
• OTHER TRANSPORTATION VEHICLES
132 - Truck, Bus, Trailer Bodies
134 - Aircraft
135 - Aircraft Engines
136 - Aircraft Equipment, NEC
137 - Ship & Boat Building
138 - Railroad Equipment
139 - Cycles, Trans Equipment, NEC
• BUILDINGS & STRUCTURES
019 - Maintenance Construction
090 - Non-Ferrous Wire Drawings
095 - Structural Metal Products
096 - Screw Machine Products
100 - Pipes, Valves, Fittings
140 - Trailer Coaches
• OTHER INDUSTRIAL APPLICATIONS
083 - Steel
084 - Copper

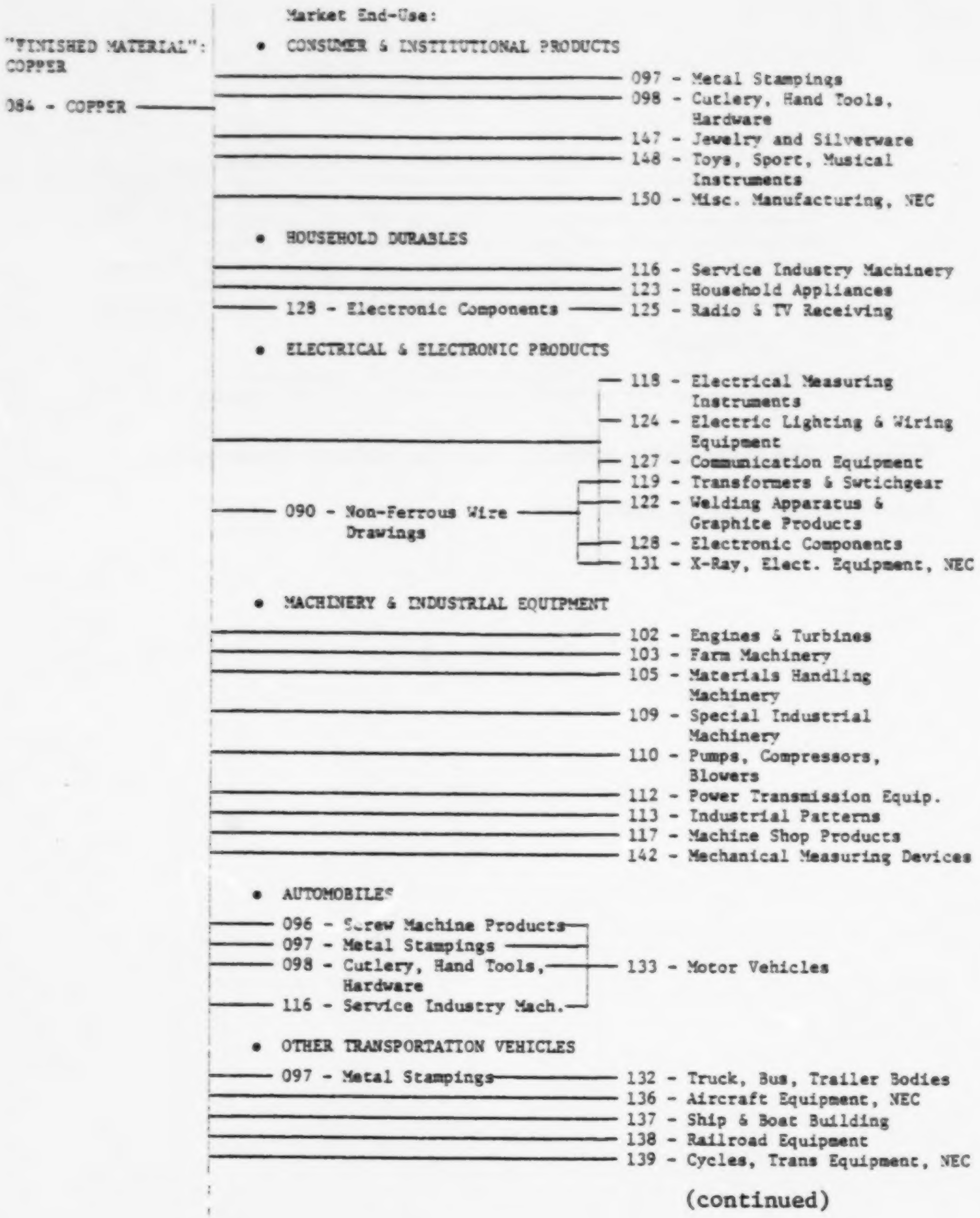
Source: International Research and Technology Corporation.

Figure A-14. (continued)


"FINISHED MATERIAL":
CONCRETE
081 -
CEMENT, CONCRETE
GYPSUM
Market End-Use:
• BUILDINGS & STRUCTURES
081 - Cement, Concrete, Gypsum

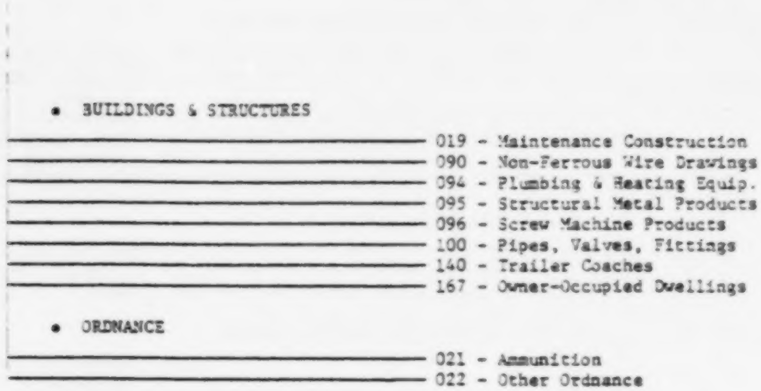
Source: International Research and Technology Corporation.

Figure A-15. Material flow paths selected for this study: concrete.


Market End-Use:
"FINISHED MATERIAL": COPPER
084 - COPPER
• CONSUMER & INSTITUTIONAL PRODUCTS
097 - Metal Stampings
098 - Cutlery, Hand Tools, Hardware
147 - Jewelry and Silverware
148 - Toys, Sport, Musical Instruments
150 - Misc. Manufacturing, NEC
• HOUSEHOLD DURABLES
116 - Service Industry Machinery
123 - Household Appliances
128 - Electronic Components
125 - Radio & TV Receiving
• ELECTRICAL & ELECTRONIC PRODUCTS
118 - Electrical Measuring Instruments
124 - Electric Lighting & Wiring Equipment
127 - Communication Equipment
119 - Transformers & Swtichgear
090 - Non-Ferrous Wire Drawings
122 - Welding Apparatus & Graphite Products
128 - Electronic Components
131 - X-Ray, Elect. Equipment, NEC
• MACHINERY & INDUSTRIAL EQUIPMENT
102 - Engines & Turbines
103 - Farm Machinery
105 - Materials Handling Machinery
109 - Special Industrial Machinery
110 - Pumps, Compressors, Blowers
112 - Power Transmission Equip.
113 - Industrial Patterns
117 - Machine Shop Products
142 - Mechanical Measuring Devices
• AUTOMOBILES
096 - Screw Machine Products
097 - Metal Stampings
098 - Cutlery, Hand Tools, Hardware
116 - Service Industry Mach.
133 - Motor Vehicles
• OTHER TRANSPORTATION VEHICLES
097 - Metal Stampings
132 - Truck, Bus, Trailer Bodies
136 - Aircraft Equipment, NEC
137 - Ship & Boat Building
138 - Railroad Equipment
139 - Cycles, Trans Equipment, NEC

(continued)

Figure A-16. Material flow paths selected for this study: copper.


• BUILDINGS & STRUCTURES
019 - Maintenance Construction
090 - Non-Ferrous Wire Drawings
094 - Plumbing & Heating Equip.
095 - Structural Metal Products
096 - Screw Machine Products
100 - Pipes, Valves, Fittings
140 - Trailer Coaches
167 - Owner-Occupied Dwellings
• ORDNANCE
021 - Ammunition
022 - Other Ordnance

Source: International Research and Technology Corporation.

Figure A-16. (continued)

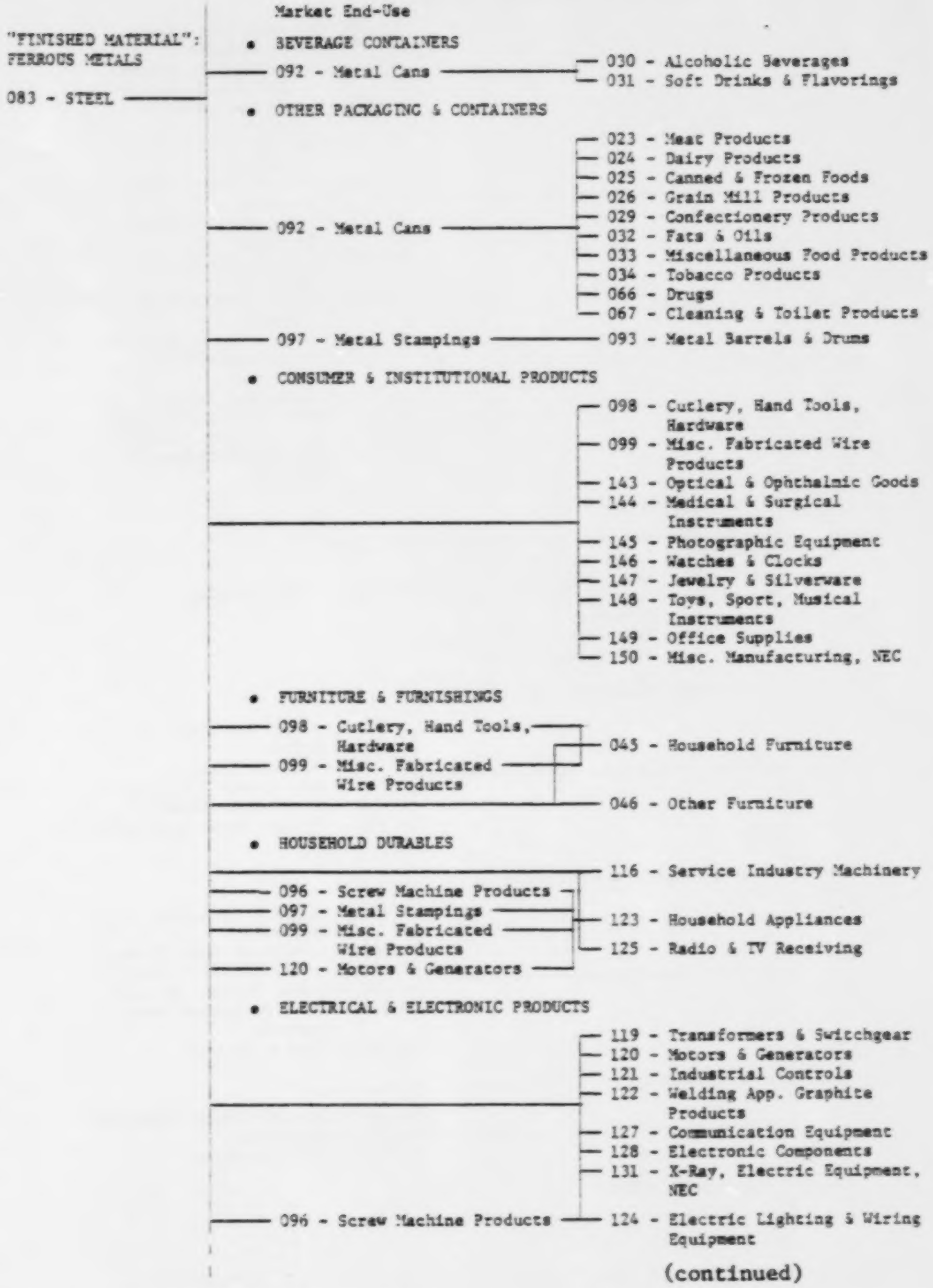
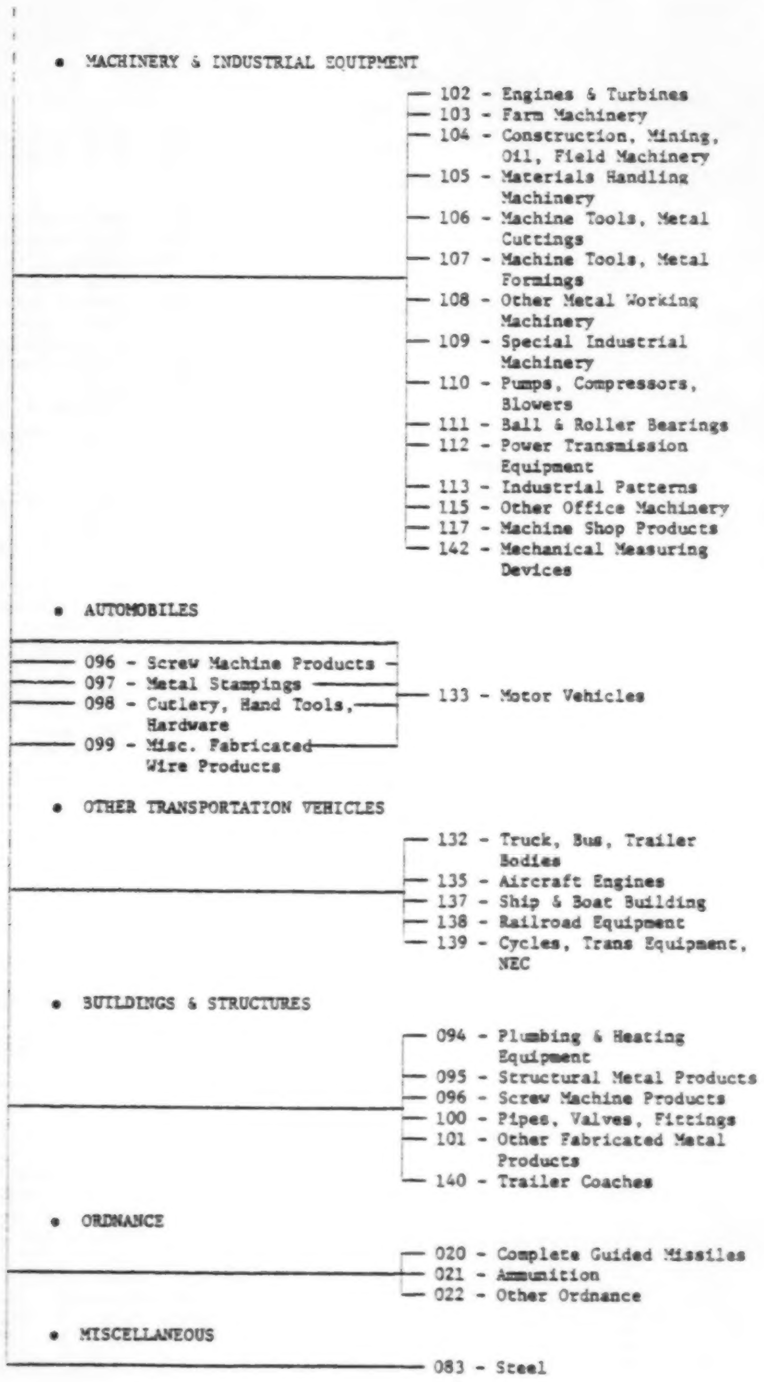
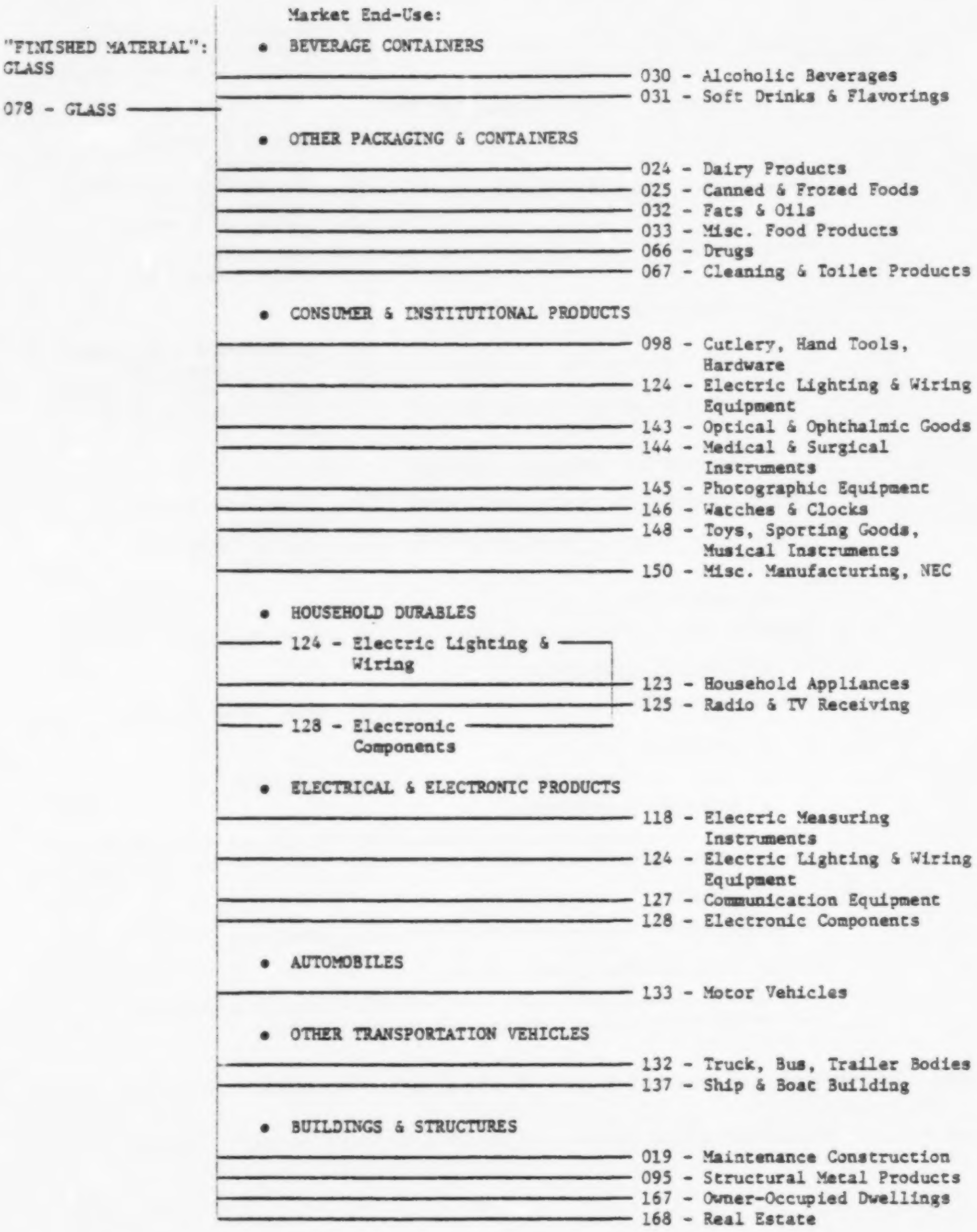

Market End-Use
"FINISHED MATERIAL":
FERROUS METALS
083 - STEEL
• BEVERAGE CONTAINERS
092 - Metal Cans
030 - Alcoholic Beverages
031 - Soft Drinks & Flavorings
• OTHER PACKAGING & CONTAINERS
092 - Metal Cans
023 - Meat Products
024 - Dairy Products
025 - Canned & Frozen Foods
026 - Grain Mill Products
029 - Confectionery Products
032 - Fats & Oils
033 - Miscellaneous Food Products
034 - Tobacco Products
066 - Drugs
067 - Cleaning & Toilet Products
097 - Metal Stampings
093 - Metal Barrels & Drums
• CONSUMER & INSTITUTIONAL PRODUCTS
098 - Cutlery, Hand Tools, Hardware
099 - Misc. Fabricated Wire Products
143 - Optical & Ophthalmic Goods
144 - Medical & Surgical Instruments
145 - Photographic Equipment
146 - Watches & Clocks
147 - Jewelry & Silverware
148 - Toys, Sport, Musical Instruments
149 - Office Supplies
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
098 - Cutlery, Hand Tools, Hardware
099 - Misc. Fabricated Wire Products
045 - Household Furniture
046 - Other Furniture
• HOUSEHOLD DURABLES
116 - Service Industry Machinery
096 - Screw Machine Products
097 - Metal Stampings
099 - Misc. Fabricated Wire Products
120 - Motors & Generators
123 - Household Appliances
125 - Radio & TV Receiving
• ELECTRICAL & ELECTRONIC PRODUCTS
119 - Transformers & Switchgear
120 - Motors & Generators
121 - Industrial Controls
122 - Welding App. Graphite Products
127 - Communication Equipment
128 - Electronic Components
131 - X-Ray, Electric Equipment, NEC
096 - Screw Machine Products
124 - Electric Lighting & Wiring Equipment
(continued)

Figure A-17. Material flow paths selected for this study: ferrous metals.


• MACHINERY & INDUSTRIAL EQUIPMENT
102 - Engines & Turbines
103 - Farm Machinery
104 - Construction, Mining, Oil, Field Machinery
105 - Materials Handling Machinery
106 - Machine Tools, Metal Cuttings
107 - Machine Tools, Metal Formings
108 - Other Metal Working Machinery
109 - Special Industrial Machinery
110 - Pumps, Compressors, Blowers
111 - Ball & Roller Bearings
112 - Power Transmission Equipment
113 - Industrial Patterns
115 - Other Office Machinery
117 - Machine Shop Products
142 - Mechanical Measuring Devices
• AUTOMOBILES
096 - Screw Machine Products
097 - Metal Stampings
098 - Cutlery, Hand Tools, Hardware
099 - Misc. Fabricated Wire Products
133 - Motor Vehicles
• OTHER TRANSPORTATION VEHICLES
132 - Truck, Bus, Trailer Bodies
135 - Aircraft Engines
137 - Ship & Boat Building
138 - Railroad Equipment
139 - Cycles, Trans Equipment, NEC
• BUILDINGS & STRUCTURES
094 - Plumbing & Heating Equipment
095 - Structural Metal Products
096 - Screw Machine Products
100 - Pipes, Valves, Fittings
101 - Other Fabricated Metal Products
140 - Trailer Coaches
• ORDNANCE
020 - Complete Guided Missiles
021 - Ammunition
022 - Other Ordnance
• MISCELLANEOUS
083 - Steel

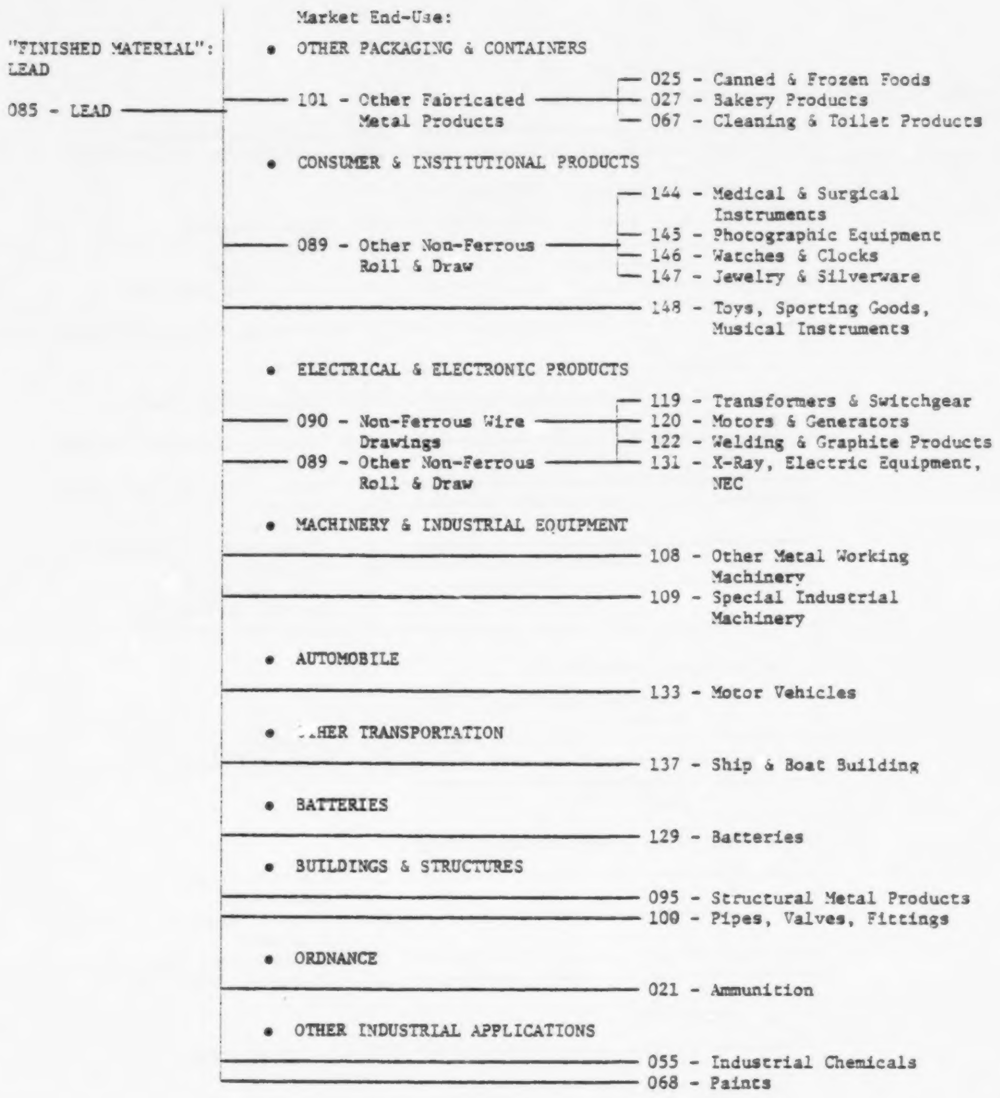
Source: International Research and Technology Corporation.

Figure A-17. (continued)


Market End-Use:
"FINISHED MATERIAL": GLASS
078 - GLASS
• BEVERAGE CONTAINERS
030 - Alcoholic Beverages
031 - Soft Drinks & Flavorings
• OTHER PACKAGING & CONTAINERS
024 - Dairy Products
025 - Canned & Frozed Foods
032 - Fats & Oils
033 - Misc. Food Products
066 - Drugs
067 - Cleaning & Toilet Products
• CONSUMER & INSTITUTIONAL PRODUCTS
098 - Cutlery, Hand Tools, Hardware
124 - Electric Lighting & Wiring Equipment
143 - Optical & Ophthalmic Goods
144 - Medical & Surgical Instruments
145 - Photographic Equipment
146 - Watches & Clocks
148 - Toys, Sporting Goods, Musical Instruments
150 - Misc. Manufacturing, NEC
• HOUSEHOLD DURABLES
124 - Electric Lighting & Wiring
123 - Household Appliances
125 - Radio & TV Receiving
128 - Electronic Components
• ELECTRICAL & ELECTRONIC PRODUCTS
118 - Electric Measuring Instruments
124 - Electric Lighting & Wiring Equipment
127 - Communication Equipment
128 - Electronic Components
• AUTOMOBILES
133 - Motor Vehicles
• OTHER TRANSPORTATION VEHICLES
132 - Truck, Bus, Trailer Bodies
137 - Ship & Boat Building
• BUILDINGS & STRUCTURES
019 - Maintenance Construction
095 - Structural Metal Products
167 - Owner-Occupied Dwellings
168 - Real Estate

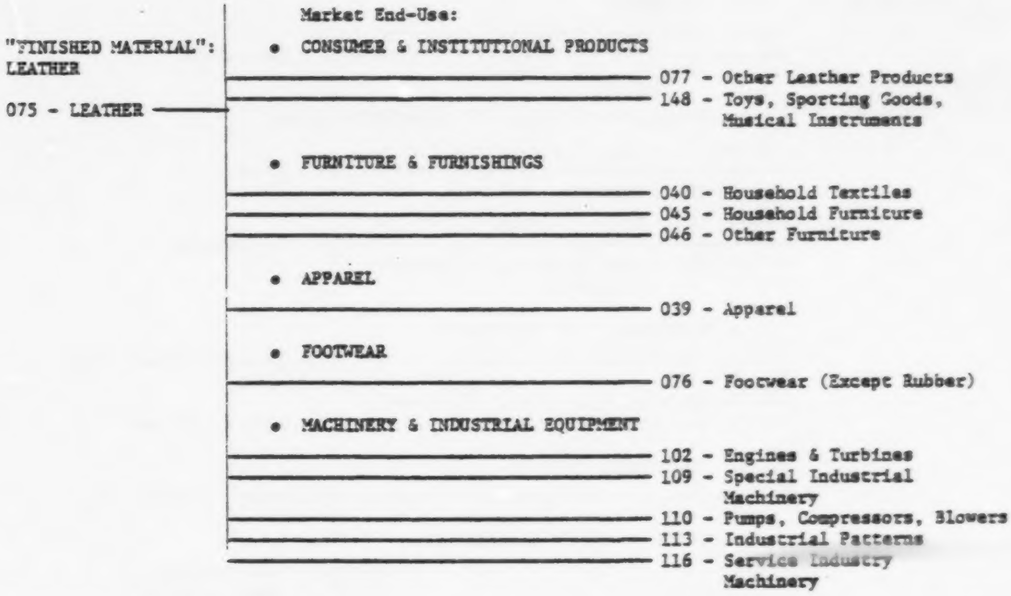
Source: International Research and Technology Corporation.

Figure A-18. Material flow paths selected for this study: glass.


Market End-Use:
"FINISHED MATERIAL": LEAD
085 - LEAD
• OTHER PACKAGING & CONTAINERS
101 - Other Fabricated Metal Products
025 - Canned & Frozen Foods
027 - Bakery Products
067 - Cleaning & Toilet Products
• CONSUMER & INSTITUTIONAL PRODUCTS
089 - Other Non-Ferrous Roll & Draw
144 - Medical & Surgical Instruments
145 - Photographic Equipment
146 - Watches & Clocks
147 - Jewelry & Silverware
148 - Toys, Sporting Goods, Musical Instruments
• ELECTRICAL & ELECTRONIC PRODUCTS
090 - Non-Ferrous Wire Drawings
089 - Other Non-Ferrous Roll & Draw
119 - Transformers & Switchgear
120 - Motors & Generators
122 - Welding & Graphite Products
131 - X-Ray, Electric Equipment, NEC
• MACHINERY & INDUSTRIAL EQUIPMENT
108 - Other Metal Working Machinery
109 - Special Industrial Machinery
• AUTOMOBILE
133 - Motor Vehicles
• OTHER TRANSPORTATION
137 - Ship & Boat Building
• BATTERIES
129 - Batteries
• BUILDINGS & STRUCTURES
095 - Structural Metal Products
100 - Pipes, Valves, Fittings
• ORDNANCE
021 - Ammunition
• OTHER INDUSTRIAL APPLICATIONS
055 - Industrial Chemicals
068 - Paints

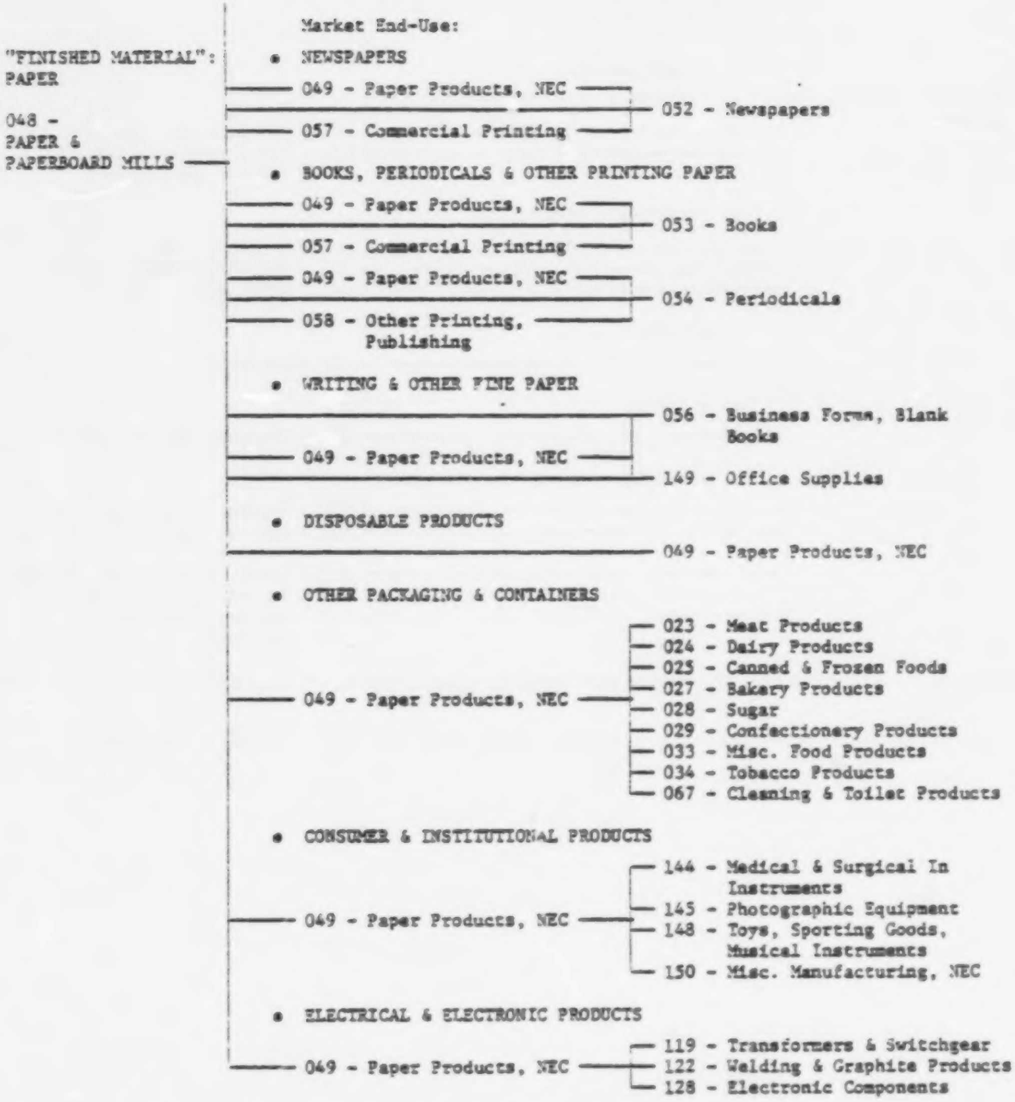
Source: International Research and Technology Corporation.

Figure A-19. Material flow paths selected for this study: lead.


Market End-Use:
"FINISHED MATERIAL": LEATHER
075 - LEATHER
• CONSUMER & INSTITUTIONAL PRODUCTS
077 - Other Leather Products
148 - Toys, Sporting Goods, Musical Instruments
• FURNITURE & FURNISHINGS
040 - Household Textiles
045 - Household Furniture
046 - Other Furniture
• APPAREL
039 - Apparel
• FOOTWEAR
076 - Footwear (Except Rubber)
• MACHINERY & INDUSTRIAL EQUIPMENT
102 - Engines & Turbines
109 - Special Industrial Machinery
110 - Pumps, Compressors, Blowers
113 - Industrial Patterns
116 - Service Industry Machinery

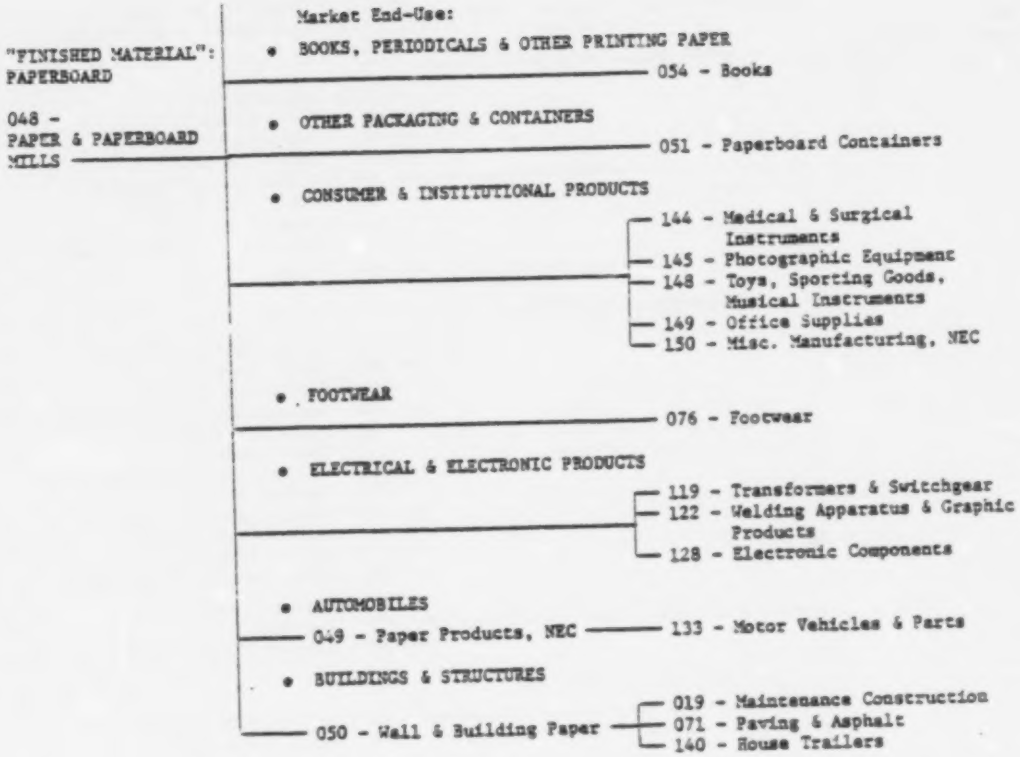
Source: International Research and Technology Corporation.

Figure A-20. Material flow paths selected for this study: leather.


Market End-Use:
"FINISHED MATERIAL": PAPER
048 - PAPER & PAPERBOARD MILLS
• NEWSPAPERS
049 - Paper Products, NEC
057 - Commercial Printing
052 - Newspapers
• BOOKS, PERIODICALS & OTHER PRINTING PAPER
049 - Paper Products, NEC
057 - Commercial Printing
053 - Books
049 - Paper Products, NEC
058 - Other Printing, Publishing
054 - Periodicals
• WRITING & OTHER FINE PAPER
056 - Business Forms, Blank Books
049 - Paper Products, NEC
149 - Office Supplies
• DISPOSABLE PRODUCTS
049 - Paper Products, NEC
• OTHER PACKAGING & CONTAINERS
049 - Paper Products, NEC
023 - Meat Products
024 - Dairy Products
025 - Canned & Frozen Foods
027 - Bakery Products
028 - Sugar
029 - Confectionery Products
033 - Misc. Food Products
034 - Tobacco Products
067 - Cleaning & Toilet Products
• CONSUMER & INSTITUTIONAL PRODUCTS
049 - Paper Products, NEC
144 - Medical & Surgical In Instruments
145 - Photographic Equipment
148 - Toys, Sporting Goods, Musical Instruments
150 - Misc. Manufacturing, NEC
• ELECTRICAL & ELECTRONIC PRODUCTS
049 - Paper Products, NEC
119 - Transformers & Switchgear
122 - Welding & Graphite Products
128 - Electronic Components

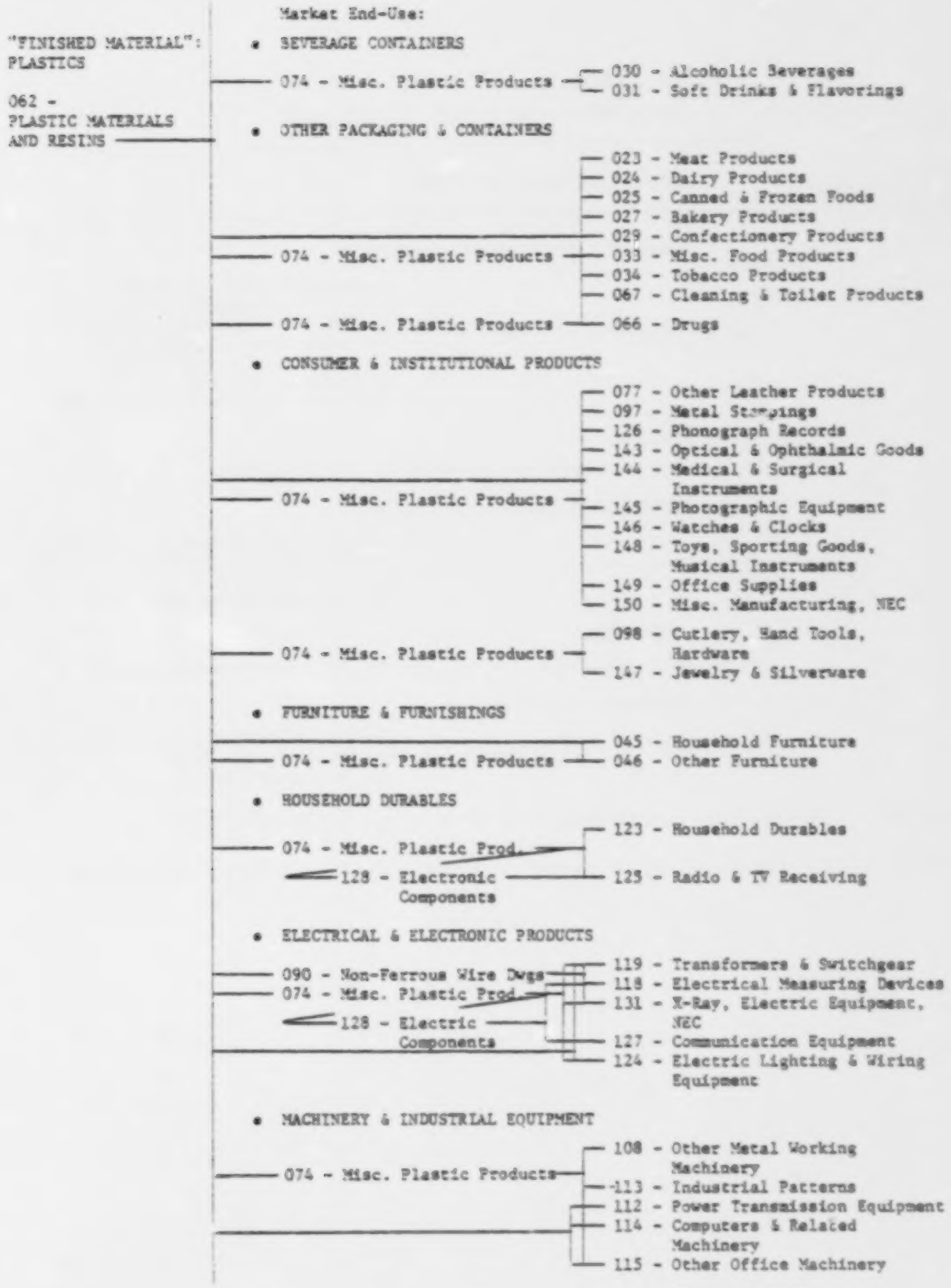
Source: International Research and Technology Corporation.

Figure A-21. Material flow paths selected for this study: paper.


Market End-Use:
"FINISHED MATERIAL":
PAPERBOARD
048 -
PAPER & PAPERBOARD
MILLS
• BOOKS, PERIODICALS & OTHER PRINTING PAPER
054 - Books
• OTHER PACKAGING & CONTAINERS
051 - Paperboard Containers
• CONSUMER & INSTITUTIONAL PRODUCTS
144 - Medical & Surgical Instruments
145 - Photographic Equipment
148 - Toys, Sporting Goods, Musical Instruments
149 - Office Supplies
150 - Misc. Manufacturing, NEC
• FOOTWEAR
076 - Footwear
• ELECTRICAL & ELECTRONIC PRODUCTS
119 - Transformers & Switchgear
122 - Welding Apparatus & Graphic Products
128 - Electronic Components
• AUTOMOBILES
049 - Paper Products, NEC
133 - Motor Vehicles & Parts
• BUILDINGS & STRUCTURES
050 - Wall & Building Paper
019 - Maintenance Construction
071 - Paving & Asphalt
140 - House Trailers

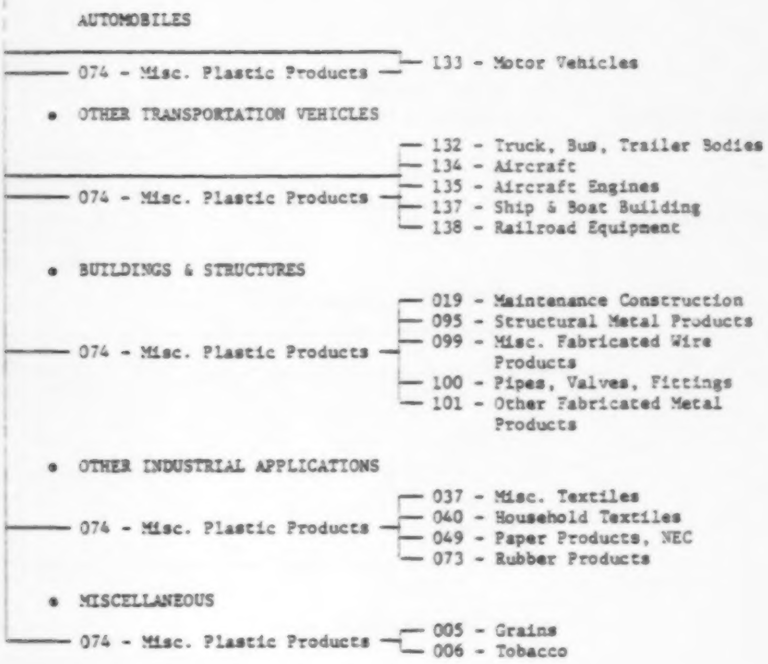
Source: International Research and Technology Corporation.

Figure A-22. Material flow paths selected for this study: paperboard.


Market End-Use:
"FINISHED MATERIAL": PLASTICS
062 - PLASTIC MATERIALS AND RESINS
• BEVERAGE CONTAINERS
074 - Misc. Plastic Products
030 - Alcoholic Beverages
031 - Soft Drinks & Flavorings
• OTHER PACKAGING & CONTAINERS
023 - Meat Products
024 - Dairy Products
025 - Canned & Frozen Foods
027 - Bakery Products
029 - Confectionery Products
074 - Misc. Plastic Products
033 - Misc. Food Products
034 - Tobacco Products
067 - Cleaning & Toilet Products
074 - Misc. Plastic Products
066 - Drugs
• CONSUMER & INSTITUTIONAL PRODUCTS
077 - Other Leather Products
097 - Metal Stampings
126 - Phonograph Records
143 - Optical & Ophthalmic Goods
144 - Medical & Surgical Instruments
074 - Misc. Plastic Products
145 - Photographic Equipment
146 - Watches & Clocks
148 - Toys, Sporting Goods, Musical Instruments
149 - Office Supplies
150 - Misc. Manufacturing, NEC
074 - Misc. Plastic Products
098 - Cutlery, Hand Tools, Hardware
147 - Jewelry & Silverware
• FURNITURE & FURNISHINGS
045 - Household Furniture
074 - Misc. Plastic Products
046 - Other Furniture
• HOUSEHOLD DURABLES
074 - Misc. Plastic Prod.
123 - Household Durables
128 - Electronic Components
125 - Radio & TV Receiving
• ELECTRICAL & ELECTRONIC PRODUCTS
090 - Non-Ferrous Wire Dwgs
074 - Misc. Plastic Prod.
128 - Electric Components
119 - Transformers & Switchgear
118 - Electrical Measuring Devices
131 - X-Ray, Electric Equipment, NEC
127 - Communication Equipment
124 - Electric Lighting & Wiring Equipment
• MACHINERY & INDUSTRIAL EQUIPMENT
074 - Misc. Plastic Products
108 - Other Metal Working Machinery
113 - Industrial Patterns
112 - Power Transmission Equipment
114 - Computers & Related Machinery
115 - Other Office Machinery

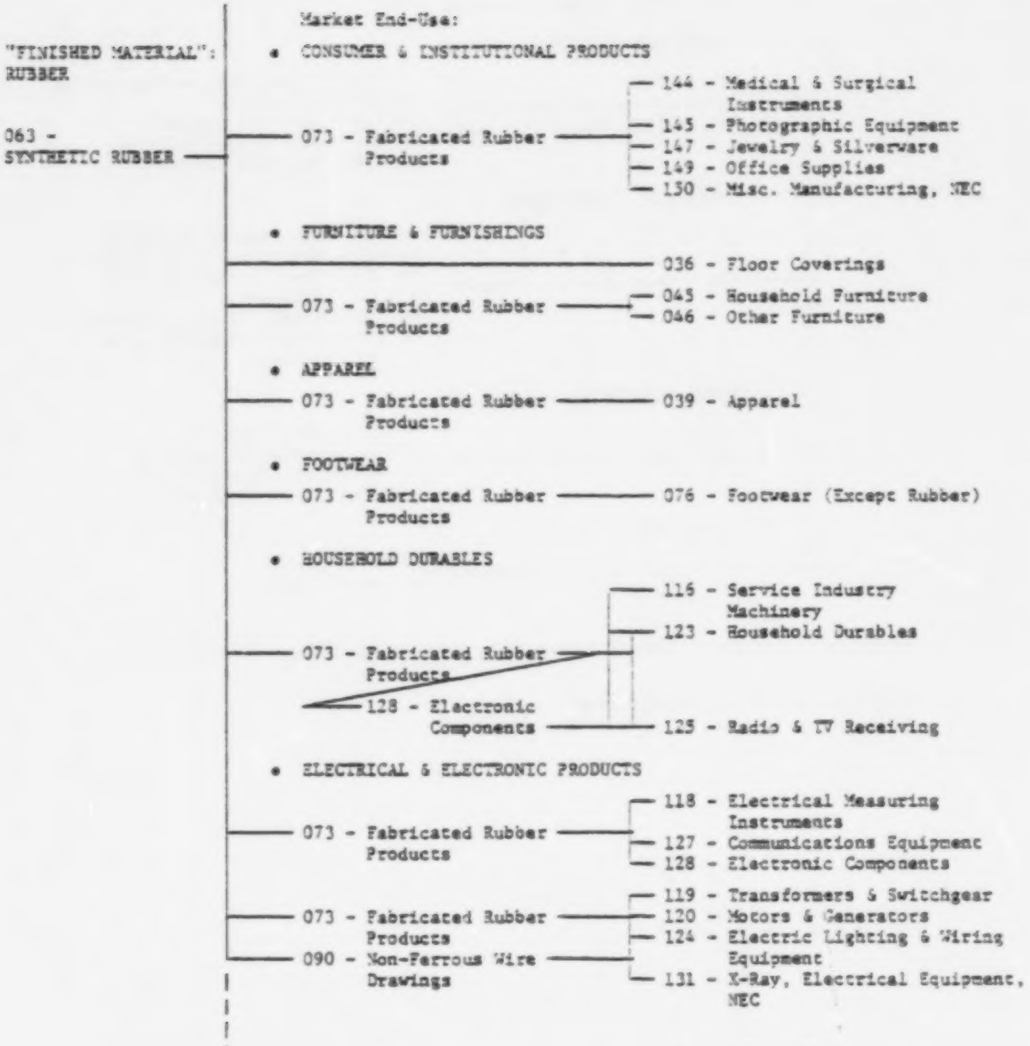
(continued)

Figure A-23. Material flow paths selected for this study: plastics.


AUTOMOBILES
074 - Misc. Plastic Products
133 - Motor Vehicles
OTHER TRANSPORTATION VEHICLES
074 - Misc. Plastic Products
132 - Truck, Bus, Trailer Bodies
134 - Aircraft
135 - Aircraft Engines
137 - Ship & Boat Building
138 - Railroad Equipment
BUILDINGS & STRUCTURES
074 - Misc. Plastic Products
019 - Maintenance Construction
095 - Structural Metal Products
099 - Misc. Fabricated Wire Products
100 - Pipes, Valves, Fittings
101 - Other Fabricated Metal Products
OTHER INDUSTRIAL APPLICATIONS
074 - Misc. Plastic Products
037 - Misc. Textiles
040 - Household Textiles
049 - Paper Products, NEC
073 - Rubber Products
MISCELLANEOUS
074 - Misc. Plastic Products
005 - Grains
006 - Tobacco

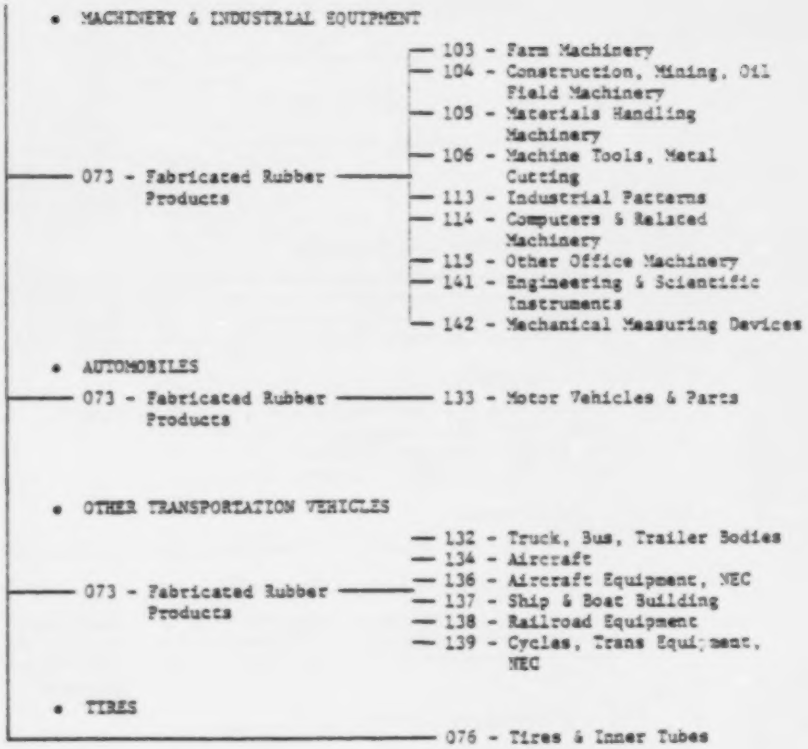
Source: International Research and Technology Corporation.

Figure A-23. (continued)


Market End-Use:
"FINISHED MATERIAL": RUBBER
063 - SYNTHETIC RUBBER
• CONSUMER & INSTITUTIONAL PRODUCTS
073 - Fabricated Rubber Products
144 - Medical & Surgical Instruments
145 - Photographic Equipment
147 - Jewelry & Silverware
149 - Office Supplies
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
036 - Floor Coverings
073 - Fabricated Rubber Products
045 - Household Furniture
046 - Other Furniture
• APPAREL
073 - Fabricated Rubber Products
039 - Apparel
• FOOTWEAR
073 - Fabricated Rubber Products
076 - Footwear (Except Rubber)
• HOUSEHOLD DURABLES
116 - Service Industry Machinery
123 - Household Durables
073 - Fabricated Rubber Products
128 - Electronic Components
125 - Radio & TV Receiving
• ELECTRICAL & ELECTRONIC PRODUCTS
118 - Electrical Measuring Instruments
073 - Fabricated Rubber Products
127 - Communications Equipment
128 - Electronic Components
119 - Transformers & Switchgear
073 - Fabricated Rubber Products
120 - Motors & Generators
124 - Electric Lighting & Wiring Equipment
090 - Non-Ferrous Wire Drawings
131 - X-Ray, Electrical Equipment, NEC

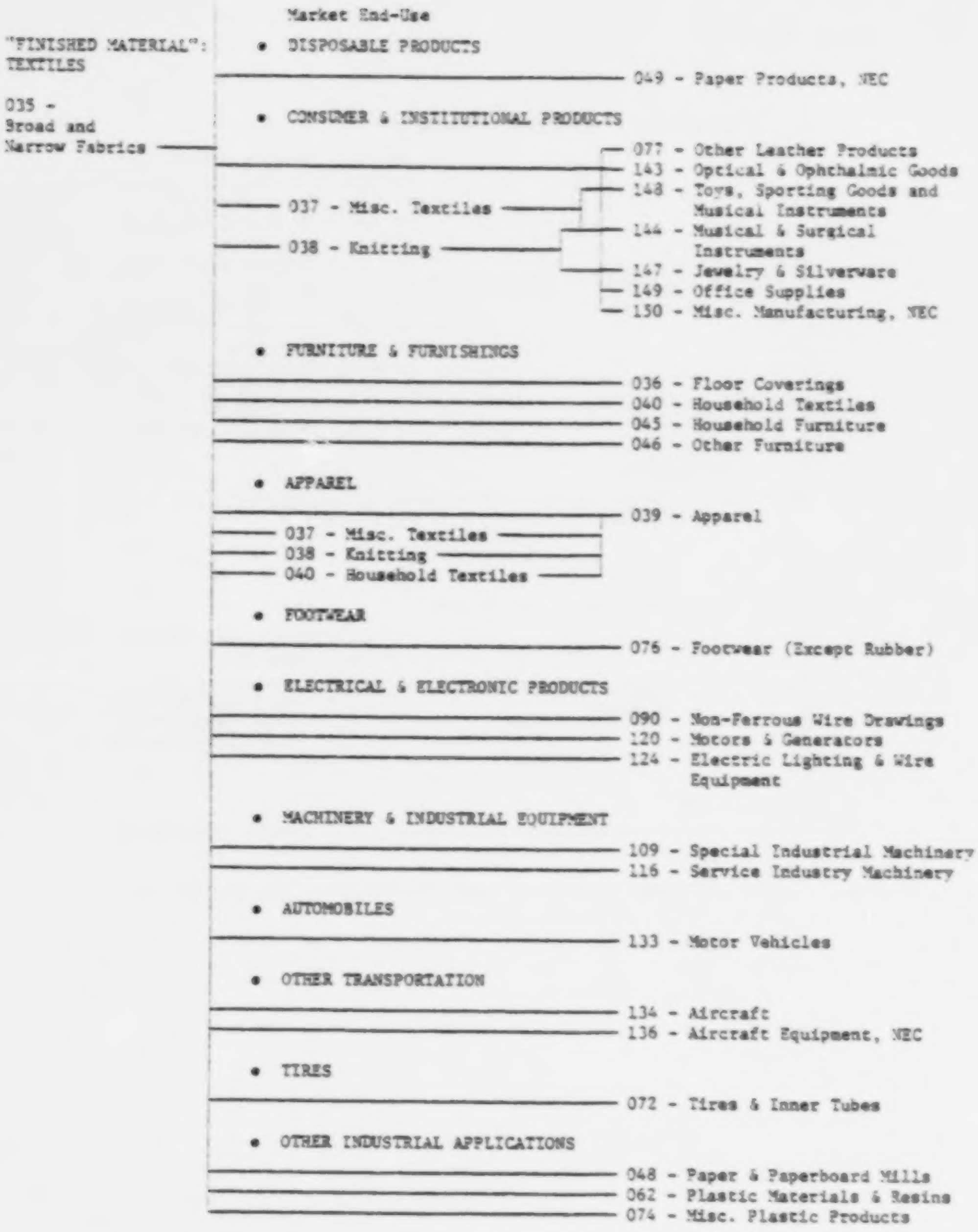
(continued)

Figure A-24. Material flow paths selected for this study: rubber.


• MACHINERY & INDUSTRIAL EQUIPMENT
073 - Fabricated Rubber Products
103 - Farm Machinery
104 - Construction, Mining, Oil Field Machinery
105 - Materials Handling Machinery
106 - Machine Tools, Metal Cutting
113 - Industrial Patterns
114 - Computers & Related Machinery
115 - Other Office Machinery
141 - Engineering & Scientific Instruments
142 - Mechanical Measuring Devices
• AUTOMOBILES
073 - Fabricated Rubber Products
133 - Motor Vehicles & Parts
• OTHER TRANSPORTATION VEHICLES
073 - Fabricated Rubber Products
132 - Truck, Bus, Trailer Bodies
134 - Aircraft
136 - Aircraft Equipment, NEC
137 - Ship & Boat Building
138 - Railroad Equipment
139 - Cycles, Trans Equipment, NEC
• TIRES
076 - Tires & Inner Tubes

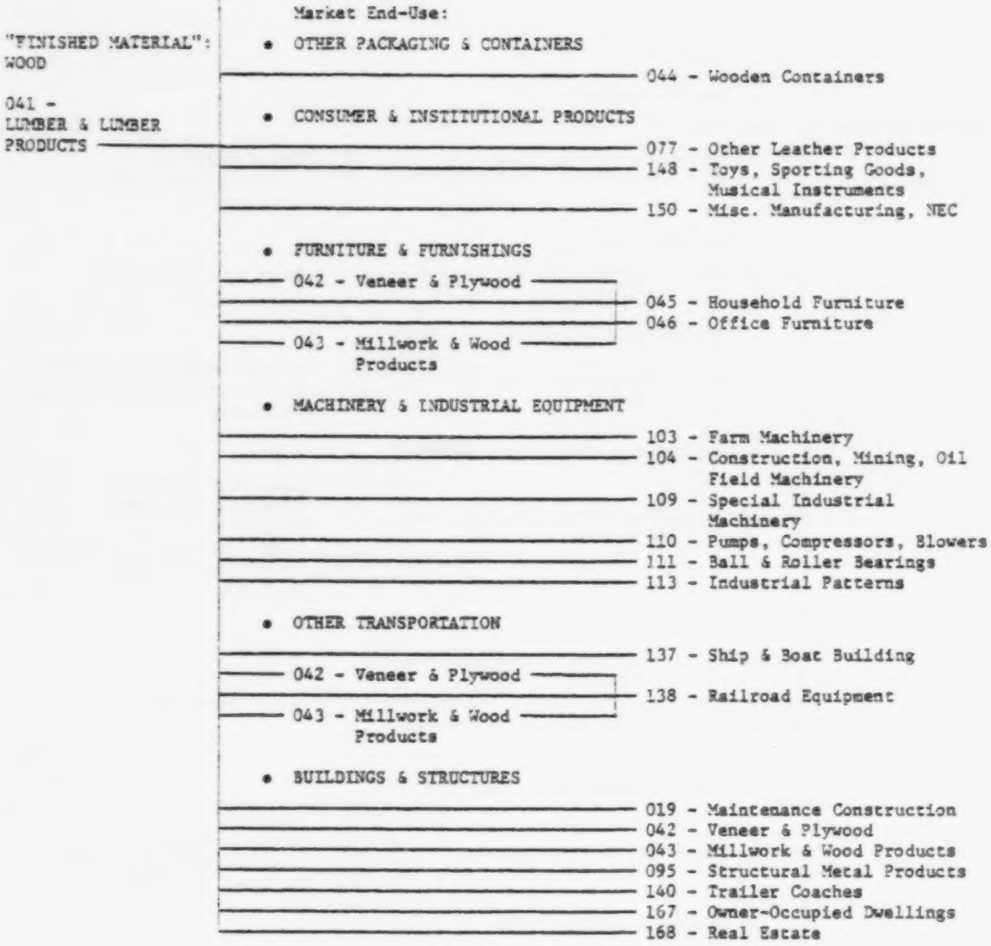
Source: International Research and Technology Corporation

Figure A-24. (continued)


Market End-Use
"FINISHED MATERIAL": TEXTILES
035 - Broad and Narrow Fabrics
• DISPOSABLE PRODUCTS
049 - Paper Products, NEC
• CONSUMER & INSTITUTIONAL PRODUCTS
077 - Other Leather Products
143 - Optical & Ophthalmic Goods
037 - Misc. Textiles
148 - Toys, Sporting Goods and Musical Instruments
038 - Knitting
144 - Musical & Surgical Instruments
147 - Jewelry & Silverware
149 - Office Supplies
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
036 - Floor Coverings
040 - Household Textiles
045 - Household Furniture
046 - Other Furniture
• APPAREL
039 - Apparel
037 - Misc. Textiles
038 - Knitting
040 - Household Textiles
• FOOTWEAR
076 - Footwear (Except Rubber)
• ELECTRICAL & ELECTRONIC PRODUCTS
090 - Non-Ferrous Wire Drawings
120 - Motors & Generators
124 - Electric Lighting & Wire Equipment
• MACHINERY & INDUSTRIAL EQUIPMENT
109 - Special Industrial Machinery
116 - Service Industry Machinery
• AUTOMOBILES
133 - Motor Vehicles
• OTHER TRANSPORTATION
134 - Aircraft
136 - Aircraft Equipment, NEC
• TIRES
072 - Tires & Inner Tubes
• OTHER INDUSTRIAL APPLICATIONS
048 - Paper & Paperboard Mills
062 - Plastic Materials & Resins
074 - Misc. Plastic Products

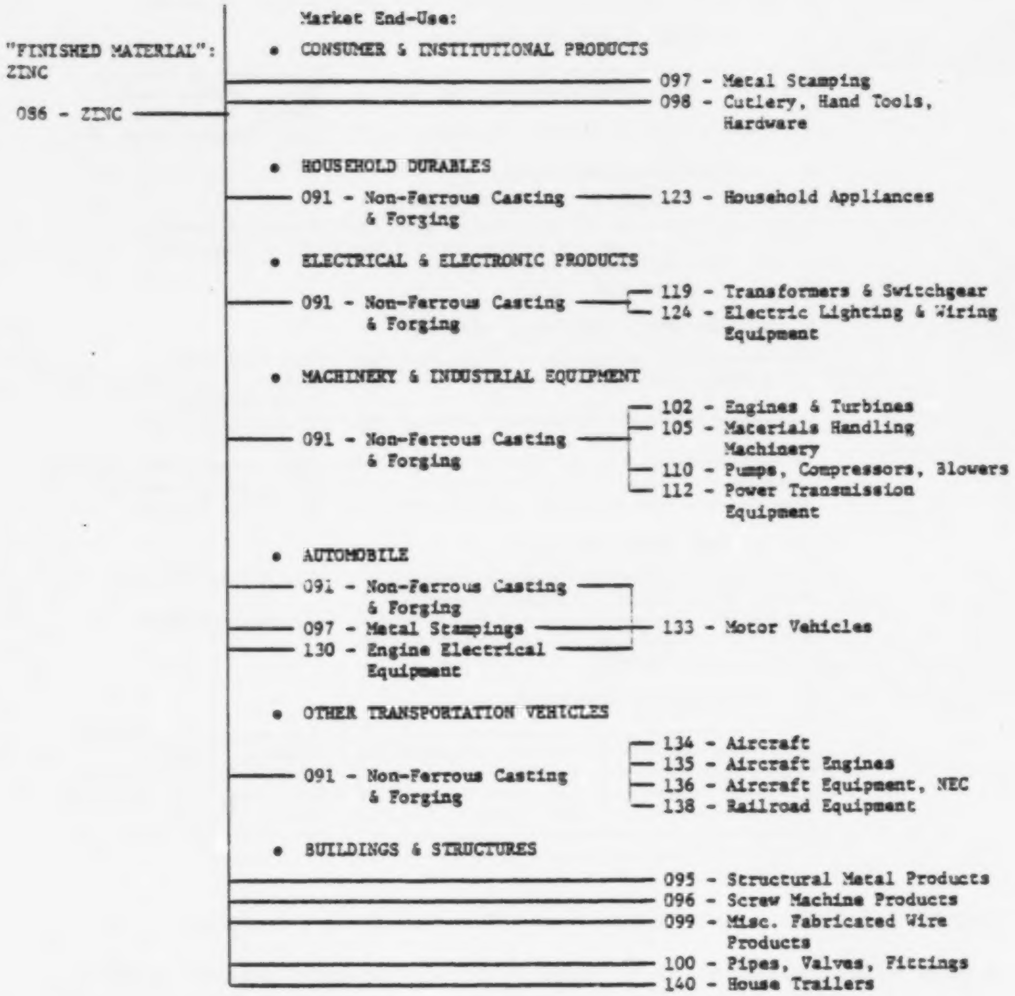
Source: International Research and Technology Corporation.

Figure A-25. Material flow paths selected for this study: textiles.


Market End-Use:
"FINISHED MATERIAL": WOOD
041 - LUMBER & LUMBER PRODUCTS
• OTHER PACKAGING & CONTAINERS
044 - Wooden Containers
• CONSUMER & INSTITUTIONAL PRODUCTS
077 - Other Leather Products
148 - Toys, Sporting Goods, Musical Instruments
150 - Misc. Manufacturing, NEC
• FURNITURE & FURNISHINGS
042 - Veneer & Plywood
045 - Household Furniture
046 - Office Furniture
043 - Millwork & Wood Products
• MACHINERY & INDUSTRIAL EQUIPMENT
103 - Farm Machinery
104 - Construction, Mining, Oil Field Machinery
109 - Special Industrial Machinery
110 - Pumps, Compressors, Blowers
111 - Ball & Roller Bearings
113 - Industrial Patterns
• OTHER TRANSPORTATION
137 - Ship & Boat Building
042 - Veneer & Plywood
138 - Railroad Equipment
043 - Millwork & Wood Products
• BUILDINGS & STRUCTURES
019 - Maintenance Construction
042 - Veneer & Plywood
043 - Millwork & Wood Products
095 - Structural Metal Products
140 - Trailer Coaches
167 - Owner-Occupied Dwellings
168 - Real Estate

Source: International Research and Technology Corporation.

Figure A-26. Material flow paths selected for this study: wood.


Market End-Use:
"FINISHED MATERIAL": ZINC
086 - ZINC
• CONSUMER & INSTITUTIONAL PRODUCTS
097 - Metal Stamping
098 - Cutlery, Hand Tools, Hardware
• HOUSEHOLD DURABLES
091 - Non-Ferrous Casting & Forging
123 - Household Appliances
• ELECTRICAL & ELECTRONIC PRODUCTS
091 - Non-Ferrous Casting & Forging
119 - Transformers & Switchgear
124 - Electric Lighting & Wiring Equipment
• MACHINERY & INDUSTRIAL EQUIPMENT
091 - Non-Ferrous Casting & Forging
102 - Engines & Turbines
105 - Materials Handling Machinery
110 - Pumps, Compressors, Blowers
112 - Power Transmission Equipment
• AUTOMOBILE
091 - Non-Ferrous Casting & Forging
097 - Metal Stampings
130 - Engine Electrical Equipment
133 - Motor Vehicles
• OTHER TRANSPORTATION VEHICLES
091 - Non-Ferrous Casting & Forging
134 - Aircraft
135 - Aircraft Engines
136 - Aircraft Equipment, NEC
138 - Railroad Equipment
• BUILDINGS & STRUCTURES
095 - Structural Metal Products
096 - Screw Machine Products
099 - Misc. Fabricated Wire Products
100 - Pipes, Valves, Fittings
140 - House Trailers

Source: International Research and Technology Corporation.

Figure A-27. Material flow paths selected for this study: zinc.

PRODUCT LIFETIME ASSUMPTIONS

One of the major parameters affecting solid waste generation is average product lifetimes. The estimates used in this study were derived from a review of the literature; the lifetime assumptions and sources of information are presented in Table A-17. Note that for some products, no source giving average product life was available. For those products, average lifetime assumptions were made on the basis of judgment.

TABLE A-17. SOLID WASTE RECYCLING MODEL REFERENCE SCENARIO. SOURCES OF AVERAGE PRODUCT LIFETIME ASSUMPTIONS (Percent Discarded by Age)

Product	Lifetime*	Source
Newspaper	94.0% - 1st year 5.0% - 1-5 years 1.0% - 5-10 years	MRI
Books & Periodicals and Other Printing Paper	70.0% - 1st year 17.0% - 1-5 years 13.0% - 5-10 years	MRI
Disposables	100% - 1st year	API
Beverage Containers	100% - 1st year	API
Other Packaging & Containers	100% - 1st year	
Consumer & Institutional Products	7 year average	A.D. Little
Furniture	10 year average	
Apparel	4 year average	
Footwear	2 year average	A.D. Little
Household Durables	10 year average	
Electrical & Electronic Products	15 year average	A.D. Little
Machinery and Industrial Equipment	20 year average	
Automobiles	10 year average	IR&T
Other Transportation	20 year average	
Tires	5 year average	
Batteries	3 year average	
Buildings and Structures	50 year average	MIT
Ordnance	5 year average	

(continued)

TABLE A-17. (continued)

Product	Lifetime*	Source
Other Industrial Applications	2 year average	
Miscellaneous	2 year average	

Source: Compiled by International Research and Technology Corporation.

* Disposal of a product for which an average lifetime is listed (i.e., all but the first six categories) is distributed over time using a frequency distribution whose graph is bell-shaped and symetrical. Thus, for products with an average life of seven years, half are disposed of between 0 and 7 years in increasing amounts annually, and half are disposed of after seven years in decreasing amounts annually.

RECYCLING ASSUMPTIONS

Introduction

The recycling rates used in this study are assumed levels based on technological trends discussed in various sources. Table A-18 shows the old scrap recycling rates for material product categories in 1971 and 1990. These old scrap or post-consumer rates are the exogenous variables that were changed in two scenarios, Constant Recycling and Increased Recycling. In the Increased Recycling Scenario, the recycling rates assumed for material in each product category was increased by ten percent, with the exception of those material product categories that have no recycling. Table A-19 shows the estimated current and assumed future new (prompt) scrap factors for each material product category and the percentage of new scrap which is recycled by marketing the material or recycling within the plant. The new scrap rate is the ratio of material discarded during the manufacture of a product to the material consumed in the fabrication of that product. The new scrap factors and the new scrap recycling rates were not changed from scenario to scenario.

Aluminum

Bureau of Mines provides data on aluminum new scrap factors which are presented in Table A-19. Present recycling levels for aluminum were obtained from estimates in *A Study to Identify Opportunities for Increased Solid Waste Utilization, Volume II* (40), by Battelle Memorial Institute. Recycled values for 1969 are presented in Table 13, page 45, for old scrap (obsolete) recyclables. Data on recycling levels for aluminum cans were derived from the Aluminum Association (48).

The maximum recycling levels of aluminum for 1990 are based on estimates and trends from *Base Line Forecasts of Resource Recovery, 1972-1990* (26) by Midwest Research Institute (MRI), 1977, and IR&T. The main increase in the recycling of obsolete aluminum will be due to the large increase in packaging and container recycling, the result of the increased efficiency of waste recovery systems for separating aluminum from other wastes.

Concrete

No recycling of concrete products is assumed.

Copper

New (prompt) scrap factors, shown in Table A-19 were derived from Bureau of Mines data. Values for the current copper recycling rates (1970) were derived from their data presented in the *Recovery of Secondary Copper and Zinc in the United States* (74) published in 1974. Levels of recycling were derived by calculating the ratio of the amounts of copper recovered from obsolete sources by product category in 1970 to amounts of obsolete copper available (recovered plus unrecovered) in 1970 by

TABLE A-18. RECYCLING RATES FOR MATERIAL PRODUCT CATEGORIES (1971 and 1990)*
(Old Scrap -- Post Consumer)

	MATERIAL													
Product Category	Paper 71/90	Paper-Board 71/90	Plas-tics 71/90	Glass 71/90	Alu-minum 71/90	Zinc 71/90	Copper 71/90	Lead 71/90	Ferrous Metals 71/90	Wood 71/90	Tex-tiles 71/90	Rub-ber 71/90	Lea-ther 71/90	Con-crete 71/90
Newspapers	.23 .30													
Books/Periodicals	.11 .16	.11 .16												
Writing Paper	.11 .16													
Disposables	.00 .00										.00 .00			
Bev. Containers			.00 .00	.02 .06	.08 .30				.11 .50					
Other Packaging	.10 .15	.17 .25	.00 .00	.02 .06	.00 .10			.62 .80	.11 .50	.00 .00				
Cons/Inst. Products	.00 .00	.10 .15	.00 .00	.00 .00	.09 .20	.06 .06	.18 .19	.14 .50	.01 .20	.00 .00	.00 .00	.00 .00	.00 .00	
Furniture			.00 .00		.09 .20				.01 .20	.00 .00	.66 .66	.00 .00	.00 .00	
Apparel											.66 .66	.00 .00	.00 .00	
Footwear		.00 .00									.00 .00	.00 .00	.00 .00	
Household Durables			.00 .00	.00 .00	.13 .25	.10 .10	.36 .38		.05 .25			.00 .00		
Elect./Electronics	.00 .00	.00 .00	.00 .00	.00 .00	.93 .95	.23 .29	.36 .38	.25 .90	.00 .10		.00 .00	.00 .00		
Machinery			.00 .00		.25 .30	.10 .10	.37 .40	.00 .00	.05 .20	.00 .00	.00 .00	.00 .00	.00 .00	
Automobiles		.00 .00	.00 .00	.00 .00	.30 .60	.20 .20	.31 .33	.00 .00	.85 .95		.00 .00	.00 .00		
Other Transp.			.00 .00	.00 .00	.30 .60	.20 .20	.31 .33	.00 .00	.85 .95	.00 .00	.00 .00	.00 .00		
Tires											.00 .00	.08 .15		
Batteries								.72 .90						
Construction		.00 .00	.00 .00	.00 .00	.13 .20	.27 .52	.29 .30	.29 .30	.10 .30					.00 .00
Ordnance							.18 .19	.14 .50	.05 .20					
Other Indus. Appl.			.00 .00		.09 .20			.00 .00	.05 .20		.00 .00			
Miscellaneous			.00 .00						.05 .20					

* Old scrap is scrap generated after consumption of products and their discard by consumers.
Old scrap recycling rates have been rounded.

Source: Compiled by International Research and Technology Corporation.

TABLE A-19. NEW SCRAP FACTORS AND NEW SCRAP RECYCLING RATES*

	MATERIAL													
Product Category	Paper NS/RF	Paper Board NS/RF	Plastics NS/RF	Glass NS/RF	Aluminum NS/RF	Zinc NS/RF	Copper NS/RF	Lead NS/RF	Ferrous Metals NS/RF	Wood NS/RF	Textiles NS/RF	Rubber NS/RF	Leather NS/RF	Concrete NS/RF
Newspapers	.03 .87													
Books/Periodicals	.15 .87	.17 .87												
Writing Paper	.06 .87													
Disposables	.05 .87										.05 .60			
Bev. Containers			.05 .58	.05 1.0	.16 .84				.12 1.0					
Other Packaging	.05 .87	.14 .87	.05 .58	.05 1.0	.16 .84			.10 .99	.12 1.0	.24 .74				
Cons/Inst. Products	.05 .87	.17 .87	.05 .58	.07 1.0	.16 .84	.15 .68	.31 1.0	.10 .99	.20 1.0	.60 .74	.05 .60	.05 .25	.15 .00	
Furniture					.16 .84				.20 1.0	.60 .74	.05 .60	.05 .25	.15 .00	
Apparel											.10 .60	.05 .25	.15 .00	
Footwear		.17 .87									.05 .60	.05 .25	.15 .00	
Household Durables			.05 .58	.08 1.0	.16 .84	.15 .68	.31 1.0		.20 1.0			.05 .25		
Elect./Electronics	.05 .87	.17 .87	.05 .58	.07 1.0	.16 .84	.15 .68	.31 1.0	.10 .99	.20 1.0		.05 .60	.05 .25		
Machinery			.05 .58		.16 .84	.15 .68	.31 1.0	.10 .99	.20 1.0	.30 .74	.05 .60	.05 .25	.15 .00	
Automobiles		.17 .87	.05 .58	.13 1.0	.16 .84	.15 .68	.31 1.0	.10 .99	.20 1.0		.05 .60	.05 .25		
Other Transportation			.05 .58	.13 1.0	.16 .84	.15 .68	.31 1.0	.10 .99	.20 1.0	.10 .74	.05 .60	.05 .25		
Tires											.05 .60	.03 .25		
Batteries								.10 .99						
Construction		.07 .87	.05 .58	.14 1.0	.16 .84	.15 .68		.10 .99	.20 1.0	.10 .74				.00 1.0
Ordnance							.31 1.0	.10 .99	.20 1.0					
Other Indus. Appl.			.05 .58					.00 1.0	.00 1.0		.05 .60			
Miscellaneous			.05 .58						.20 1.0					

*The new scrap factor (NS) reflects the fraction of material throughput contributing to new scrap. The new scrap recycling rate (RF) reflects the fraction of new scrap re-used inhouse or elsewhere. These assumptions are held constant over time. New scrap rates have been rounded.

Source: Compiled by International Research and Technology Corporation.

product end-use category. In mathematical terms,

$$\frac{CR_{1970}}{CR_{1970} + CU_{1970}}$$

where CR is copper recovered form obsolete sources, and
CU is copper unrecovered from obsolete sources.

Projections of copper recycling rates for 1990 are based on a ratio of the amount of copper expected to be recovered in 1990, to the amount of copper expected to be available (recovered plus unrecovered). This data is also available in the Bureau of Mines report.

Ferrous Metals

EPA's Office of Solid Waste provided data on new scrap factors for ferrous metals as shown in Table A-19. Recycling level estimates (1970) of ferrous metals were derived from estimates in two reports sponsored by EPA, *Economic and Technological Impediments to Recycling Obsolete Ferrous Solid Waste* (75) by the National Environmental Research Center (NERC), 1973, *Base Line Forecasts of Resource Recovery, 1972-1990* (26) by MRI, 1975, and IR&T estimates.

Packaging and container recycling levels were derived from the data shown in the Appendix (obsolete scrap supply from steel products) of the NERC report. Discussion on pages 33-35 of this report projects increased container recycling due to the use of tin-free steel. Values for household durables are based on the discussion on pages 37-39 in the NERC publication. Problems of contaminants, porcelain coating, and low yield of steel per article shredded reduce the desireability of recycling household products. Automotive and transportaion levels are based on NERC's estimate of present car recycling (85%). Values for "Other Consumer Goods" are derived from the MRI report (pp. 79,90), assuming that container ferrous scrap in municipal waste is from "Other Consumer Products." Construction recycling of ferrous metals are based on discussion of building and industrial plant demolition (pp. 222-224) in *Identification of Opportunities for Increased Recycling of Ferrous Solid Waste,* (37). Other recycling assumptions for machinery, electronics, and other metal products are IR&T estimates.

Glass

New scrap generation factors are derived from Census data on cullet consumption (57). Adjustments for assumed recycling levels of glass containers are derived from the Glass Packaging Institute's data (56).

Lead

New (prompt) scrap factors for lead are derived from Bureau of Mines data. Estimates for lead recovery are based on *A Study to*

Identify Opportunities for Increased Solid Waste Utilization, Volume IV (40) by Battelle Memorial Institute, and IR&T estimates. It is assumed that estimates of recycling rates for lead products applies to product end-use categories in the study. For instance, recycling rate estimates for cable sheathing applies to the electrical and electronics product category, foil applies to other packaging and containers, pipe fittings and sheet to buildings and structures, and ammunition, solders and beaming lead to other metal products.

Projections of recycling rates for 1990 are based on estimates in the Battelle-Columbus report. Large increases are projected for lead recovery due to the phasing out of tetra-ethyl lead in gasoline. Large savings are expected in cable recycling by the year 1990. The other trend in lead recovery is a marked increase in the recycling rate of batteries by 1990, as shown in Table A-18.

Leather

A new (prompt) scrap factor of 15% is assumed in this study. No recycling of post-consumer leather is assumed.

Paper and Paperboard

A summary of the recycling assumptions made for new scrap and old scrap for paper is presented in Table A-20. The source of most of the assumptions is the American Paper Institute's report, *1976-1979 Capacity: Paper, Paperboard, Woodpulp* (76) and William Franklin's estimates for the EPA's Office of Solid Waste annual *Report to Congress* (36).

Plastics

As shown in Table A-18, no recycling of obsolete plastic scrap is assumed for the years 1971 through 1990. The A.D. Little study, *Incentives for Recycling and Reuse of Plastics* (64) indicates that all sources of industrial plastics from manufacture to distribution are included in these estimates. New scrap in this study includes scrap conversion of the material and fabrication of the product. The new scrap estimates were reduced from a previous estimate of 6.1% to 4.9% as indicated in Table A-19. The recycling of the new scrap, generally by marketing the material, is assumed to be 58% of the new scrap generation.

Rubber

New (prompt) scrap estimates were taken from the EPA report *A Solid Waste Estimation Procedure: Materials Flow Approach* (27), 1975. Estimates of rubber tire recycling of 8.3 percent in 1971 were taken from the Rubber Manufacturers Association (65) data on reclaimed rubber usage. Rubber tire recycling is projected to increase to 15% in 1990. Rubber use diverted from tread is assumed to be 10 percent from the Markiewcz and Gransky study *Solid Waste Management and Rubber Reuse Potential in the Rubber Industry: Waste Rubber and Its Use, 1968* (77).

TABLE A-20. NEW SCRAP AND OLD SCRAP RECYCLING AND DIVERSION ASSUMPTIONS FOR PAPER AND PAPERBOARD WASTES

	Percent Recycled	Source
PAPER		
Newspaper		
New Scrap	2.5%	MRI/Franklin/API
% Recycled	87.0%	EPA
Diversion	.5%	MRI
Old Scrap		
• Base (1971)	23.0%	API
• Projected (1990)	30.0%	IR&T
Other Printing Paper		
New Scrap	15.0%	MRI
% Recycled	87.0%	
% Diverted	7.0%	MRI
Old Scrap		
• Base (1971)	11.0%	API
• Projected (1990)	16.0%	IR&T
Writing & Other Fine Paper		
New Scrap	6.1%	MRI
% Recycled	87.0%	EPA
% Diverted	6.0%	MRI
Old Scrap		
• Base (1971)	11.0%	API
• Projected (1990)	16.0%	IR&T
Disposable Paper		
New Scrap	5.0%	MRI
% Recycled	87.0%	EPA
% Diverted	31.0%	MRI
Old Scrap		
• Base (1971)	0.0%	API
• Projected (1990)	0.0%	
Electrical & Electronic Products		
New Scrap	5.0%	EPA
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	

(continued)

TABLE A-20. (continued)

	Percent Recycled	Source
Other Packaging & Containers		
New Scrap	5.0%	MRI
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	10.0%	API
• Projected (1990)	15.0%	IR&T
Consumer & Institutional Products		
New Scrap	5.0%	MRI
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	
PAPERBOARD		
Other Packaging & Containers		
New Scrap	13.6%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	16.5%	API
• Projected (1990)	25.0%	IR&T
Books, Periodicals and Other Printing Paper		
New Scrap		
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	11.0%	
• Projected (1990)	16.0%	
Consumer & Institutional Products		
New Scrap	17.0%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	10.0%	API
• Projected (1990)	15.0%	IR&T

(continued)

TABLE A-20. (continued)

	Percent Recycled	Source
Footwear		
New Scrap	17.0%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	
Electrical & Electronic Products		
New Scrap	17.0%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	
Automobiles		
New Scrap	17.0%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	
Buildings & Structures		
New Scrap	6.5%	
% Recycled	87.0%	EPA
% Diverted	0.0%	
Old Scrap		
• Base (1971)	0.0%	
• Projected (1990)	0.0%	

Source: API, *Paper, Paperboard, Woodpulp Capacity*, annual report, "Waste Paper in Paper and Paperboard Manufacture."

Franklin, estimates for EPA's Office of Solid Waste's Annual *Report to Congress*.

EPA, Office of Solid Waste, *A Solid Waste Estimation Procedure: Materials Flow Approach*, EPA/530/SW-147, 1975.

A.D. Little, *Incentives for Recycling and Reuse of Plastics*, Study for EPA, PB 214045, 1972, Table 35, p. III-40.

New scrap factors and recycling estimates were derived from the Battelle study, *A Study to Identify Opportunities for Increased Solid Waste Utilization* (40).

Wood

Estimates for new scrap and recycling rates were taken from EPA's Office of Solid Waste. No recycling of post-consumer (old scrap) wood products is assumed in this study.

Zinc

The source of the zinc new scrap factors is data from the Bureau of Mines. Current zinc recycling rates (1970) are derived from data in the *Recovery of Secondary Copper and Zinc in the United States* (74) published by the Bureau of Mines in 1974. Zinc recycling levels were derived by calculating the ratio of the amounts of zinc recovered from obsolete sources by each product category in 1970 to the amounts of zinc available (recovered plus unrecovered) from obsolete recovery in 1970 by product end-use category. As discussed previously in the section on copper recycling, the ratio calculated to obtain zinc recycling by product category is the same ratio calculated to obtain copper recycling by end-use. In mathematical terms,

$$\frac{ZR_{1970}}{ZR_{1970} + ZU_{1970}}$$

where ZR is zinc recovered from obsolete sources, and
ZU is zinc unrecovered from obsolete sources.

Projections of the percentage of zinc expected to be recycled in 1990 are based on a ratio of the amount of zinc projected to be recovered in 1990, to the amount of zinc available (recovered and unrecovered). This data was also available in the Bureau of Mines report.

Categories were coupled for both 1970 and 1990 estimates as follows:

Product Category	Bureau of Mines Categories
Construction	Agricultural, Mining and Construction Equipment, Roofing and Construction
Electrical	Electronic Equipment, Rod and Wire
Automobiles	Automotive
Other Transportation	Other Transportation
Machinery	Machinery and Tools, Office Equipment
Other	All Other Categories Listed